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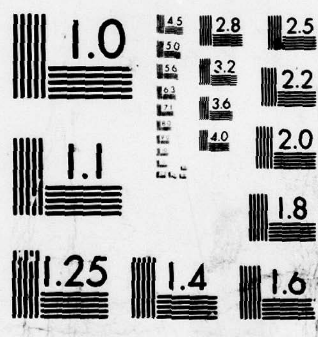

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DESIGN ASSESSMENT OF ADVANCED TECHNOLOGY LIGHTWEIGHT, LOW-COST MISSION-CONFIGURED GONDOLA MODULES

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July 1979

Final Report for Period August 1978 - March 1979

Approved for public release;
distribution unlimited.

Prepared for

APPLIED TECHNOLOGY LABORATORY
U. S. ARMY RESEARCH AND TECHNOLOGY LABORATORIES (AVRADCOM)
Fort Eustis, Va. 23604

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APPLIED TECHNOLOGY LABORATORY POSITION STATEMENT

Previously conducted research and development effort (USAAMRDL-TR-77-28, "Gondola System for Helicopter Transport of External Cargo") provided the design and fabrication of experimental gondola units for operational suitability and force development testing and experimentation evaluations. Although these experimental units demonstrated the technical feasibility and major productivity improvements available through use of a gondola system, it was equally apparent that configuration and technological improvements were needed prior to full development of the concept.

The program reported herein is a follow-on effort to the above. The basic objectives of this effort were to analyze, assess, and select advanced technology materials and compatible, efficient structural design arrangements for a low-cost, lightweight, aerodynamically stable family of gondolas. This Laboratory concurs in the design concepts recommended in the report. However, because the proposed design approach uses extensive advanced metallic and nonmetallic structural arrangements, verification testing to demonstrate overall structural integrity is considered to be essential prior to initiating development of the gondola concept. Accordingly, a program is planned for FY79 to design, fabricate, and test critical elements/components and full-scale gondola assemblies; this effort will provide the necessary knowledge to complete a low risk engineering development program.

Mr. S. G. Riggs, Jr., Aeronautical Systems Division, served as Project Engineer for this effort.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The objectives of this program were to identify applicable high strength materials and efficient structural concepts for application to various elements of the helicopter external gondola system (HEGS) and to subsequently prepare preliminary design arrangements for the HEGS-10, HEGS-20, and HEGS-Palletized modules.

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PREFACE

This investigation of advanced gondola modules was performed under Contract Number DAAK51-78-C-0012 from the Applied Technology Laboratory, U. S. Army Research and Technology Laboratories (AVRADCOM), Fort Eustis, Virginia. Solomon Riggs, Jr., of the Applied Technology Laboratory provided technical direction for the program.

The work was performed at the Kaman Aerospace Corporation facilities in Bloomfield, Connecticut. John Porterfield was the principal engineer.

The author gratefully acknowledges the help of Solomon Riggs of Applied Technology Laboratory, who brought to our attention the previous research, the results of Army evaluations of earlier gondolas, and his own insight into the operational uses of the gondola modules. The author is also grateful to Robert Mayerjak and George Haire of Kaman Aerospace Corporation for their contributions to the development of concepts and analyses throughout the program.

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INTRODUCTION

Full productivity of Army helicopters cannot be obtained using existing cargo nets, slings, and MILVAN containers. The operational mission of Army cargo and utility helicopters, particularly the CH-47 and the UH-60, requires the development of a family of gondolas which provide a more effective, efficient, and safe means for the external transport of noncontainerized cargo such as breakbulk/general cargo, equipment, spare parts, rations, ammunition, weapons systems, and vehicles.

In an earlier effort reported in Reference 1, two experimental gondola systems were fabricated and successfully proof-loaded. The Army then performed experimental service tests to determine their operational suitability. These tests demonstrated the technical feasibility of the gondola concept and identified configurations and technological improvements essential to logistical, combat, and combat service support missions. Foremost among the required improvements was the need for a large (about 60%) reduction in weight. To achieve such a large weight reduction while still maintaining a practical, low-cost gondola appropriate for Army field use requires the development of new structural concepts that are more efficient than conventional structures.

The objective of the present program is to develop such improved concepts for a family of gondolas. Included in this report are:

1. Detailed description of the preferred gondola concepts

2. Cost and weight estimates

3. Identification of operational features and advantages of the preferred concepts

4. Rationale for the selection of preferred concept

5. Discussion of alternative structural arrangements and materials that were considered, with reasons why they were judged to be less beneficial than the preferred concepts

6. Preliminary stress analyses for the preferred gondola concept.

1. GONDOLA SYSTEM FOR HELICOPTER TRANSPORT OF EXTERNAL CARGO, Brooks and Perkins, Inc., USAAMRDL-TR-77-28, Applied Technology Laboratory, U. S. Army Research and Technology Laboratories (AVRADCOM), Fort Eustis, Virginia, September 1977, ADA047560.

Eleven major parameters were recognized and used to guide the development and evaluation of concepts and materials:

1. Weight
2. Cost
3. Aerodynamic stability
4. Impact resistance
5. Wear resistance
6. Environmental stability
7. Repairability and maintainability
8. Rapid load and unload capability
9. Multipurpose versatility
10. Compatibility with Army cargo and utility helicopters
11. Compatibility with automated lifting devices and ground transport equipment.

PREFERRED CONCEPTS

The family of gondolas has three members which have the following names, sizes, and purposes:

1. HEGS-10. General purpose 8-foot x 10-foot cargo gondola. Transport breakbulk/general cargo, equipment, spare parts, rations, ammunition.

2. HEGS-20. General purpose 8-foot x 20-foot cargo gondola. Transport breakbulk/general cargo, equipment, spare parts, rations, ammunition, artillery, vehicles.

3. HEGS-Palletized. Palletized cargo gondola. Configured to accept 463L pallets (463L Air Cargo Handling System, MIL-A-8421D) or 40-inch x 48-inch pallets, and other specialized palletized cargo.

The preferred concepts for each gondola type are shown in Figure 1. Each gondola is a welded aluminum cable-truss which has a perforated plate floor system. The gondolas are closely related in structural configuration, fabrication method, and materials. It will be found that much of the description and rationale presented for the HEGS-10 also applies to the HEGS-20 and HEGS-Palletized.

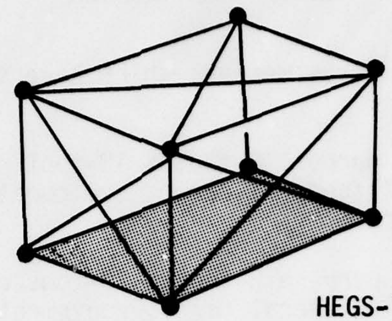
HEGS-10 GONDOLA MODULE

Figure 2 shows the preferred configuration for the HEGS-10 gondola module. This module is 10 feet long, 8 feet wide, 8-1/2 feet in height, and conforms to ANSI document MH 5.1-1971 (Reference 2) dimensional requirements for 10-foot-long units, as shown in Figure 3. The effective minimum lateral interior width is 88 inches. Its fully loaded design gross weight is 8,000 pounds. The design loading conditions for the HEGS-10 module are described in Appendix A. The following list of ultimate loads from Appendix A shows the magnitude of loading for which the gondola was designed:

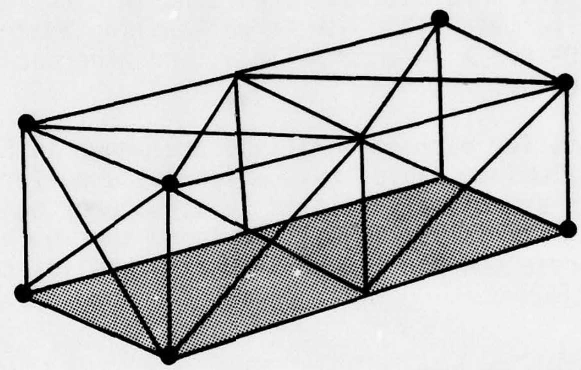
1. An ultimate load of 38.4 kips applied at the load center of gravity for the single-point suspension and the two-point suspension flight conditions

2. An ultimate downward load of 21.6 kips applied to the load center of gravity of the upper module of a two-module high

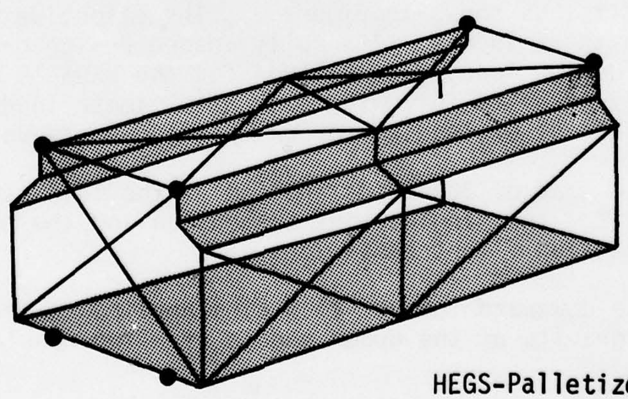
2. BASIC REQUIREMENTS FOR CARGO CONTAINERS, ANSI MH 5.1-1971, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, New York 10017.



HEGS-10

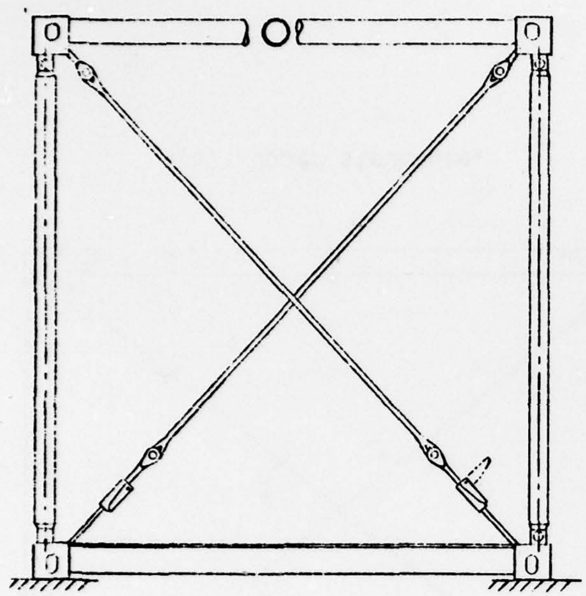


HEGS-20

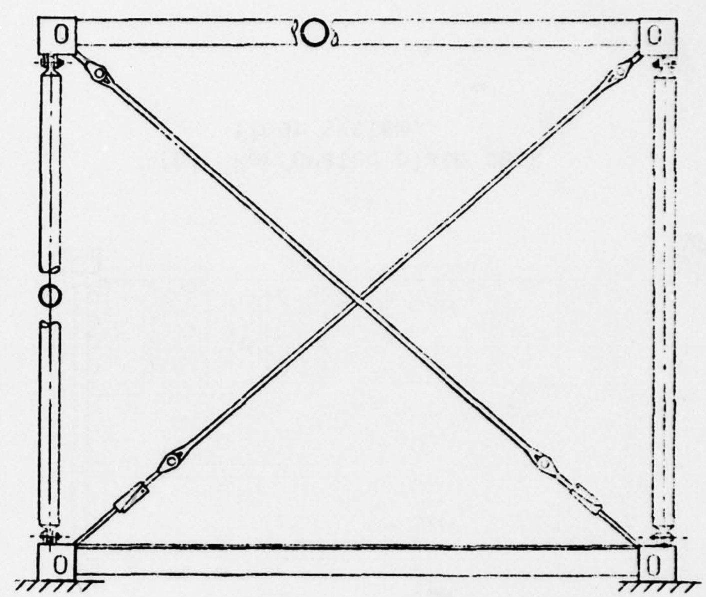


HEGS-Palletized

Figure 1. Preferred family of gondolas.

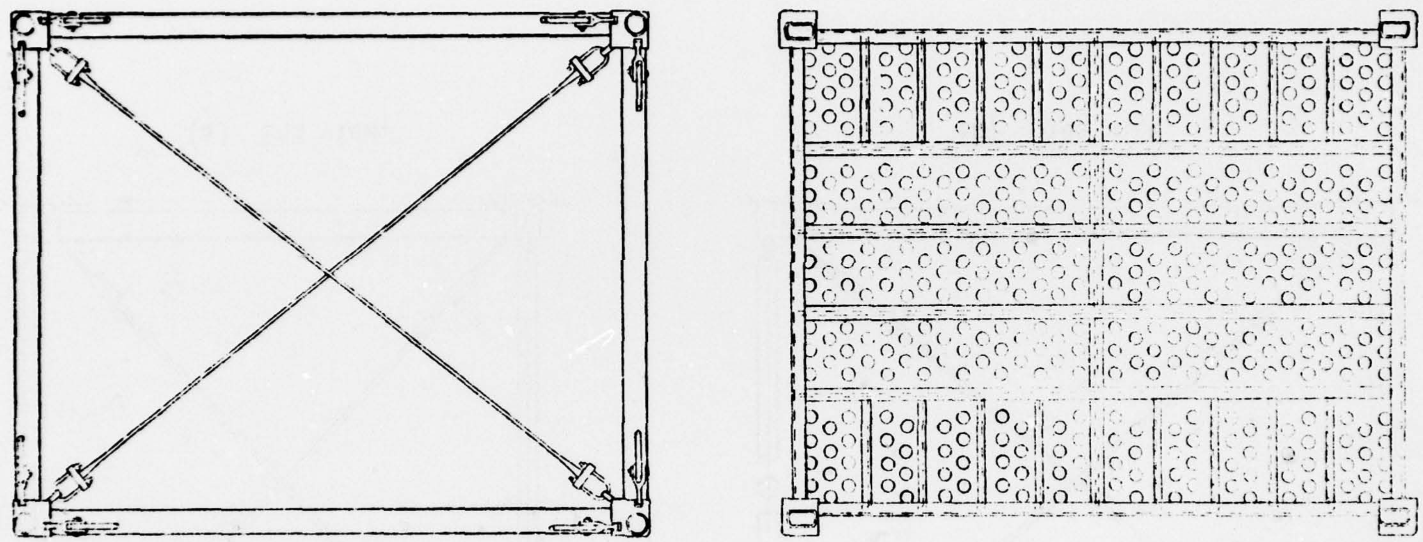


(a) End view.



(b) Side view.

Figure 2. HEGS-10 preferred configuration.

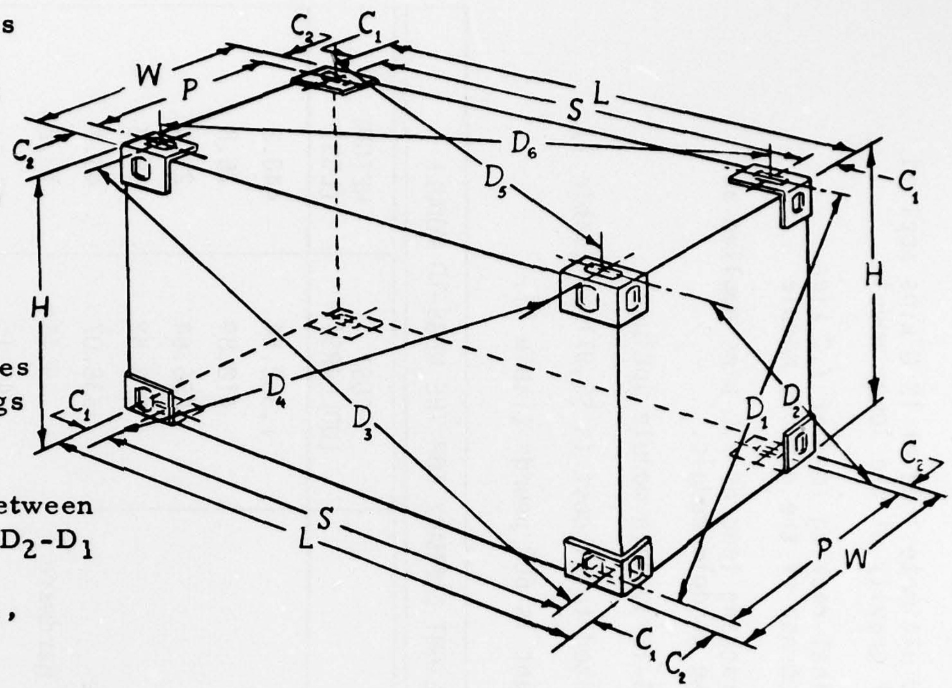


(a) Upper structure.

(b) Perforated plate deck floor system.

Figure 2. Continued.

S = Length between centers of apertures in corner fittings
P = Width between centers of apertures in corner fittings
C_1 = Corner fitting measurement: 4 +0-0.06 inches (101.5 +0-1.5 mm)
C_2 = Corner fitting measurement: 3.5 +0-0.06 inches (89 +0-1.5 mm)
L = External length of container
W = External width of container
D = Distance between center of apertures of diagonally opposite corner fittings resulting in six measurements: D_1, D_2, D_3, D_4, D_5 and D_6
K_1 = Difference between D_1 and D_2 or between D_3 and D_4; i.e., $K_1=D_1-D_2$ or $K_1=D_2-D_1$ or $K_1=D_3-D_4$ or $K_1=D_4-D_3$
K_2 = Difference between D_5 and D_6; i.e., $K_2=D_5-D_6$ or $K_2=D_6-D_5$
H = Overall height



Nominal Length Feet	Length Overall (L)		S			P			K_1 Max.		K_2 Max.	
	mm	Ft In.	mm	Ft	In.	mm	Ft	In.	mm	In.	mm	In.
20	6055 + 3-3	19 10.50 +0-0.25	5853	19	2.44	2259	7	4.97	13	0.50	10	0.38
10	2990 + 1-4	9 9.75 +0-0.18	2787	9	1.72	2259	7	4.97	10	0.38	10	0.38

Width Overall (W): 8 ft 0 in. + 0-0.18 in. (2435 + 3-2mm)
Height Overall (H): 8 ft 6.5 in. + 0-0.75 in. (2600 + 3-16 mm)

NOTE: Dimensions S and P are reference dimensions only. The tolerances to be applied to S and P are governed by the tolerances shown for the overall length (L) and overall width (W).

Figure 3. ANSI document MH 5.1-1971 dimensional requirements.

stack, and a downward ultimate load of 12.0 kips applied to the load center of gravity of the lower module

3. An ultimate longitudinal-racking load of 7.2 kips applied at an upper corner of the gondola module

4. An ultimate lateral-racking load of 7.2 kips applied at an upper corner of the gondola module.

Prominent features of the HEGS-10 gondola module include:

1. Low Cost - The estimated total cost is $2,971.24 (Table 1).

2. Low Weight - The weight is 602 pounds (Table 1).

TABLE 1. COST AND WEIGHT SUMMARY FOR THE HEGS-10 MODULE

ITEM	COST (DOLLARS)	WEIGHT (LBS)
Floor Assembly	1,382.54	440.2
Upper Structure	418.89	76.8
Corner Columns	255.64	23.4
Diagonal Cables	518.52	8.2
Cable Attachment Hardware	338.07	43.4
Miscellaneous Attachment Hardware	9.43	10.2
Packaging	48.15	---
TOTALS	2,971.24	602.2

3. Aerodynamic Stability - Low drag profile is obtained for the unloaded module through the use of the perforated floor, circular tube members, and cable diagonals.

4. Impact Resistance -

   a. Hard landing. Impact energy is accommodated and absorbed through structural flexibility, the use of high ductility materials, load limiting diagonals, and bearing mounted superstructure.

   b. Cargo handling. Perforated floor can be dented and even punctured without loss of structural capacity because of the alternative load paths provided by the redundancy of the structure.

5. Wear Resistance - The metallic floor member has a substantial 3/16-inch thickness which provides an inherent high resistance to wear.

6. Environmental Stability - Corrosion-resistant materials are used throughout the structure.

7. Repairability - Repairs are made by welding. The materials selected have high structural strength after welding without post-weld heat-treatment. Columns and diagonals may be readily replaced if excessively damaged.

8. Rapid Load and Unload Capability -

   a. Rapid removal of end or side diagonals is accomplished without tools by loosening turnbuckles and removing T-bar fittings from lower corner fittings.

   b. Positive ramp retention precludes slip-off during use.

   c. Flush-mounted tiedown fittings.

   d. Rapid removal of auxiliary tiedown fittings.

   e. Provisions for preventing fold-down of superstructure when the end or side diagonals are removed.

9. Multipurpose Versatility -

   a. The gondola module can be converted into a pallet by removing the four lower column attachment bolts and the lower diagonal attachment fittings.

   b. The floor can be equipped with wheels or skids to convert the module into a trailer or sled.

   c. The module can be converted into a container by enclosing the top and the sides.

   d. The modules may be rapidly disassembled for transport by removing eight bolts and the diagonals.

10. Compatibility With Army Cargo and Utility Helicopters -

   a. Structural and functional compatibility with the YH-60 utility helicopter or the CH-47D cargo helicopter for either the single-point or two-point suspension condition is accomplished through compliance with the established design requirements.

b. The safety of personnel attaching lift slings to a helicopter is enhanced by the use of column-mounted steps or platforms.

11. Compatibility With Automated Lifting Devices and Ground Transport Equipment - Compliance with the geometry requirements for cargo containers specified in ANSI document MH 5.1-1971 and the structural design requirements specified in Appendix A of this report should insure compatibility with the Army's automated lifting devices and ground transport equipment.

As shown in Figures 2 and 4, the basic subassemblies of the HEGS-10 cable-truss structural arrangement include the perforated plate deck floor system, upper structure, vertical columns, and upper, side and end diagonals.

Floor Structure

The welded aluminum floor system is a perforated deck plate supported by stringers, end beams, side beams, intercostals, and standard International Organization for Standardization (ISO) corner fittings. Local intercostals between the side beams and the outer stringers reinforce the floor perimeter. This floor concept offers the following advantages:

1. Aerodynamic stability
2. Low weight
3. Low cost
4. Large capacity to support high local overloadings
5. Torsional flexibility which permits racking without damage during hard landings on uneven ground
6. High impact and wear resistance
7. Ease of repair by welding without post-weld heat-treatment
8. Good corrosion resistance.

This floor system resists large overloads by structurally efficient membrane action. Membrane action allows the loads to be supported primarily by axial tensions, rather than bending. The structural analyses presented in Appendix A describe further the high load capability of the floor and present test results from a similar floor.

Impact loads caused by normal landings and corner strikes are accommodated by elastic deformation of the structure. In the case of extraordinary hard landings, links in the diagonals are designed to yield and absorb the

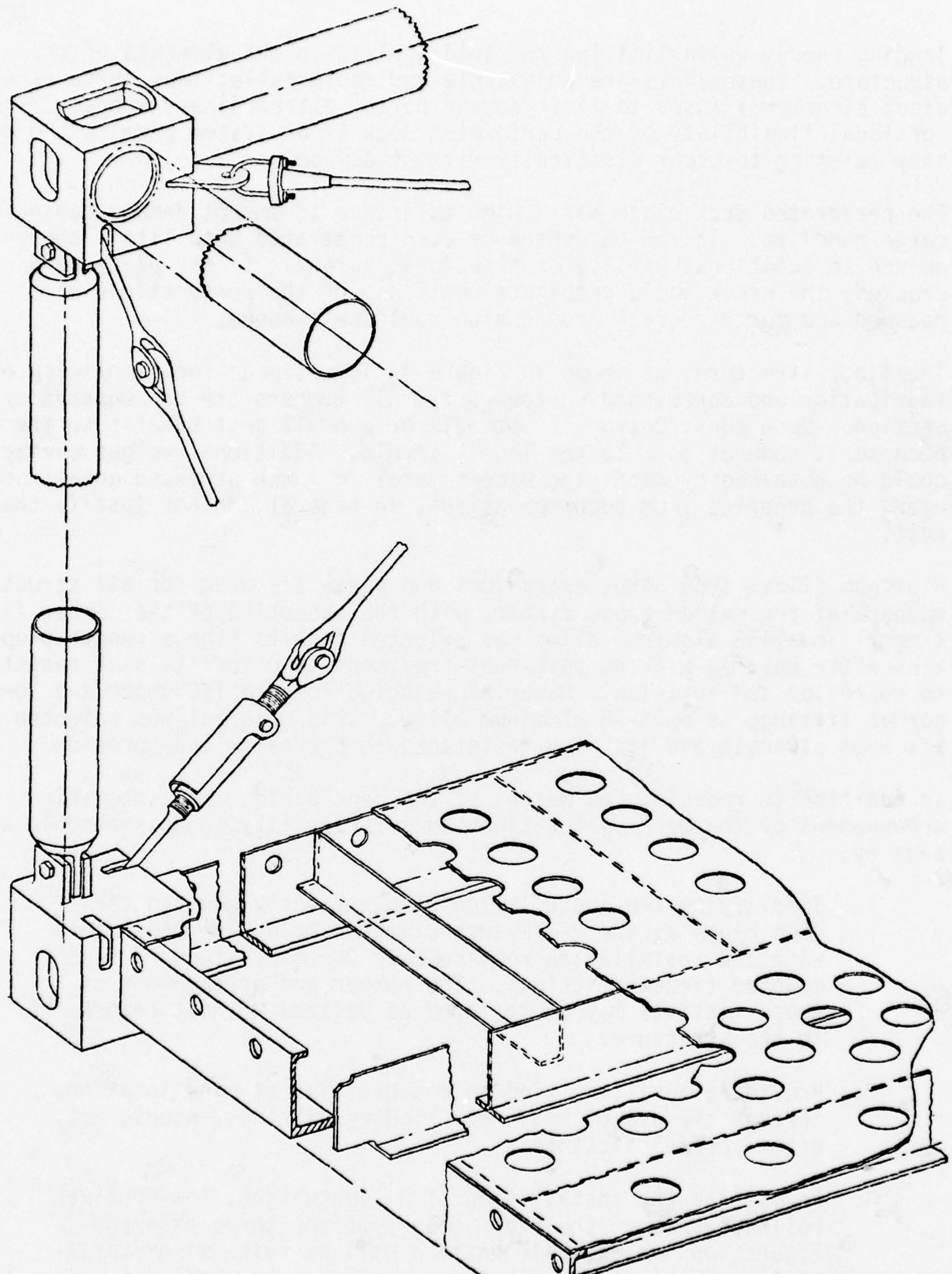


Figure 4. Corner details for HEGS-10 and HEGS-20 preferred configurations.

landing energy while limiting the load applied to the elements of the structure. These links are adjustable and replaceable; they serve as efficient structural fuses to limit damage during extraordinary events. The torsional flexibility of the perforated deck floor system permits the necessary twisting to occur elastically without damage.

The perforated deck plate has a high tolerance to impact damage caused by cargo handling. It can be dented or even penetrated with little consequence to functional utility or structural safety. If the plate were cracked, the crack would propagate until one of the perforations were reached and further crack progression would be stopped.

The floor structure, as shown in Figure 4, is designed for simplicity of fabrication and corresponding low cost. All members are of constant cross section. Such construction is optimal for overall cost benefit to the Army because it reduces cost to the lowest levels. Additional weight savings could be obtained by machining excess metal in lower stressed areas; however, the benefits from such operations, in general, do not justify their cost.

Aluminum alloy, type 5456, extrusions and plate are used for all structural members of the welded floor system, with the exception of the corner fittings. The 5456 aluminum alloy was selected for its high strength properties after welding with no post-heat-treatment, and for its high resistance to corrosion and abrasion. Material selected for the ISO upper and lower corner fittings is 6066-T6 aluminum alloy. This material was selected for its high strength and its high resistance to corrosion and abrasion.

In addition to reducing the weight of the deck plate, the systematic arrangement of the deck perforations adds versatility to this gondola concept by:

1. Simplifying the installation of permanently mounted tiedown rings as the 2-1/2-inch-diameter holes are compatible with the installation requirements for many standard flush-mounted tiedown fittings. The number and arrangement of these fittings may be tailored as desired without rework to the structure.

2. Providing auxiliary tiedown capabilities at many locations through the use of temporary tiedown fittings, hooks, or other special fittings.

3. Permitting the installation of a lightweight, low-profile roller system on the floor of any of the three base configurations as the hole pattern will be (with minor variations) identical for all three modules. It should be noted that the orientation of one hole to another forms a hexagon pattern. The hexagon pattern permits the ligaments between holes to be of equal length and width, and thus, of equal strength.

4. Permitting the rapid installation and removal of guide rails and wheel chocks.

The end and side members are designed to form a strong perimeter around the floor structure for resisting impact strikes on landing and resisting the concentrated loads caused by cargo handling equipment and other wheeled vehicles driving on and off the floor. A systematic pattern of retention holes is located in the web of the end and side members around the periphery of the floor. These holes provide a means for attaching loading ramps at many positions to accommodate loading or unloading operations from the ends or sides. Figure 5 shows a loading ramp in its installed position. The geometry of the attached end of the ramp positively locks the ramp to the module and precludes a slip-off during operational use.

Upper Structure

The geometry of the HEGS-10 upper structure conforms to the geometric requirements of ANSI document MH 5.1-1971 for 10-foot-long units (Figure 3). The upper structure is a rectangular frame consisting of aluminum tubing welded to standard ISO corner fittings and prevented from racking out of alignment by the fixity of the welded tube-to-corner fitting attachment and by the use of Kevlar-cable diagonals.

Several corrosion-resistant aluminum alloys were considered in establishing a weight-strength efficient tube for the compression-loaded upper frame members. The materials were reviewed for their basic yield strengths in the buckling-critical central portion of tube, and for their ultimate and yield strengths in the welded heat-affected zones at the ends of the tube. Of the weldable aluminum alloys, 6061-T6 is attractive because of its high yield strength before welding and its adequate ultimate and yield strengths in the welded heat-affected zone.

The upper frame structure is capable of resisting impact loads and hard landings without failure. Large out-of-plane bending and twisting deformations can be tolerated without exceeding the yield strengths of the individual members.

Vertical Columns

The vertical columns supporting the upper structure are subjected to both tension and compression loads. They consist of two forged 6061-T6 aluminum lug end fittings welded to a section of 6061-T6 aluminum tubing. Inexpensive monoball bearings are mounted in the lug portion of each end fitting to minimize the transfer of bending moments to the columns, which could otherwise induce permanent deformation during hard landing. A total of eight bolts are used to attach all the vertical columns to the upper and lower corner fitting lugs. The 3-3/4-inch-diameter, .049-inch-thick tubing is capable of withstanding high impact loads by deforming elastically or, in severe cases, inelastically. In the event that a column is damaged severely, it can be removed for repair and a replacement installed by

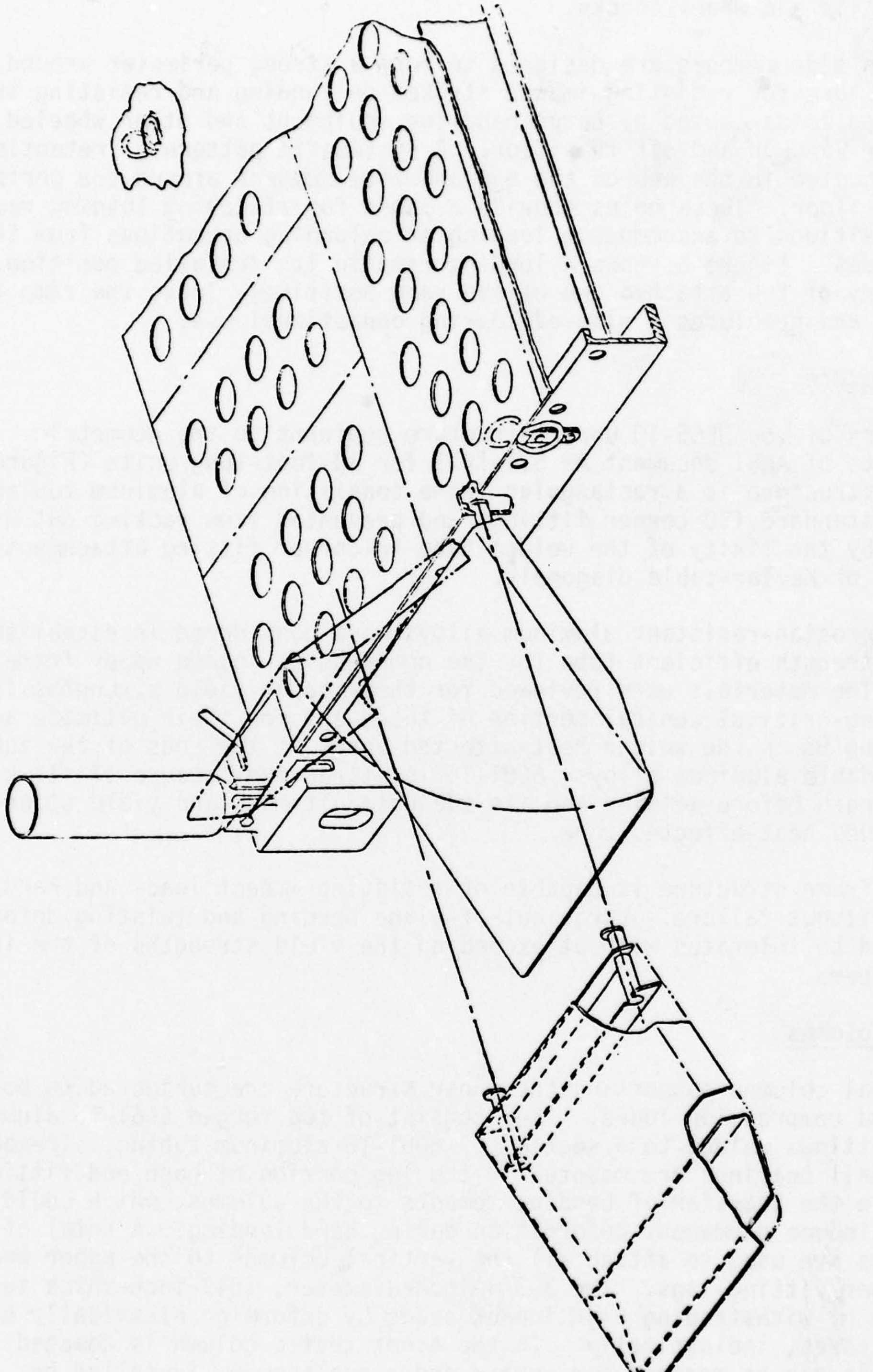


Figure 5. Loading ramp and its installation procedure.

disconnecting and replacing only two bolts. End fittings may be salvaged and reused. However, their low cost makes many such procedures unnecessary.

Diagonals

Upper, side, and end diagonals are used to maintain the required squareness of the HEGS-10 gondola module by resisting racking loads. High-strength, low-weight Kevlar cables having 17-4 PH stainless steel attachment fittings at each end were selected as the preferred diagonal design. Side and end diagonals have an adjustable T-bar fitting at the lower end and a nonadjustable T-bar fitting at the upper end. Upper diagonals are similar, but U-bolt end attachments are substituted for the T-bar attachments to reduce cost and weight.

Figure 6 shows the details of the lower adjustable T-bar attachment fitting. This design incorporates:

1. A turnbuckle that is used to adjust the length and to apply preload to the diagonal assembly

2. A relatively long, reduced-diameter, energy-absorbing section

3. A T-bar attachment fitting used to facilitate the rapid installation and removal of the diagonal assembly

4. A permanently attached handle to facilitate adjusting the diagonals without the use of tools

5. A square shaft on one member and a square hole in the other member which prevents twisting of the cable as the assembly is adjusted by the handle.

Impact loads during hard landings are limited and energy is absorbed by the axial stretching of the diagonal assembly with the major portion of the deformation occurring in the long, reduced-diameter portion of the fitting. The bars are made from 17-4 PH corrosion-resistant steel which has good ductility.

The T-bar portion of the fitting is used to simplify the rapid installation or removal of the diagonal assembly. The T-bar need only be inserted into the corner fitting slots and turned 90 degrees to accomplish the connection. Advantages of this system include:

1. No pins or bolts to be removed, lost, or broken

2. No tools required for the installation or removal of the diagonal assembly

3. Cables are semiflexible and resist damage due to bending

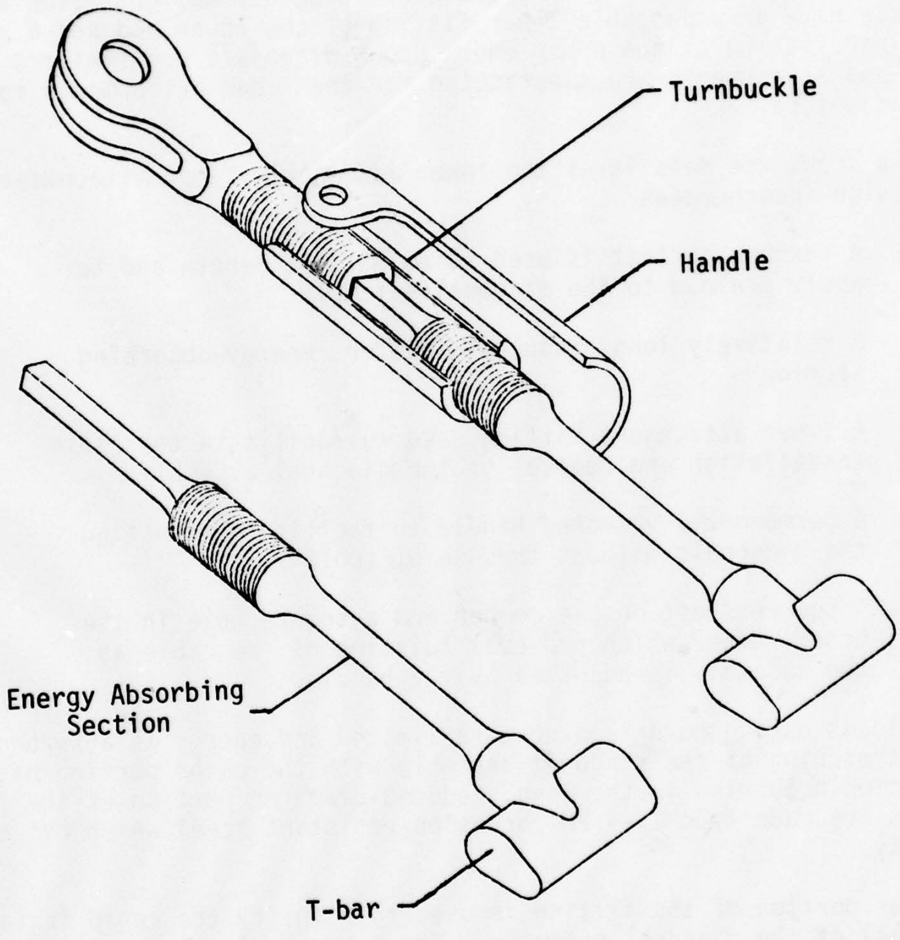


Figure 6. T-bar diagonal attachment fitting.

4. Corrosion-resistant materials used throughout

5. Large adjustment capability

6. No sharp edges to injure personnel

7. In the event that the diagonals are severely damaged, they may be easily replaced.

U-bolt connections can be used for the upper diagonal system because these members are not removed during normal side or end loading and unloading operations. If access for top loading or unloading were required, T-bar end fittings could be used instead of the U-bolt connections shown in Figure 2.

HEGS-20 GONDOLA MODULE

Figure 7 presents the preferred design concept for the HEGS-20 gondola module. Features incorporated in this design are essentially the same as previously described for the HEGS-10 gondola module. Variations that do occur, such as increases in length, in member sizes, and in the number of members required, are necessary to accommodate the special function and load requirements of the HEGS-20 module.

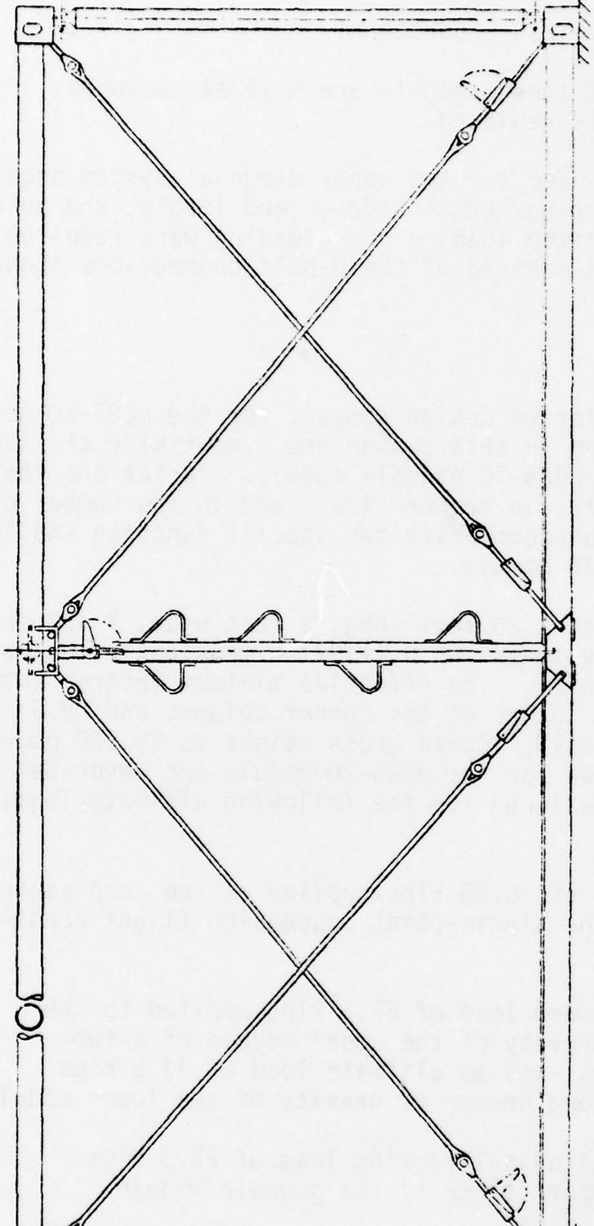
The HEGS-20 gondola module is 20 feet long, 8 feet wide, 8-1/2 feet high, and conforms to the ANSI document MH 5.1-1971 dimensional requirements for 20-foot-long units (Figure 3). The effective minimum lateral interior width of the module is 88 inches at the corner columns and 89.5 inches at the center columns. Its fully loaded gross weight is 25,000 pounds. The design conditions and loads for the HEGS-20 module are described in Appendix A. The gondola was designed for the following ultimate loads (from Appendix A):

1. An ultimate load of 86.25 kips applied at the load center of gravity for the single-point suspension flight condition

2. An ultimate downward load of 67.5 kips applied to the load center of gravity of the upper module of a two-module high stack, and an ultimate load of 37.5 kips applied to the load center of gravity of the lower module

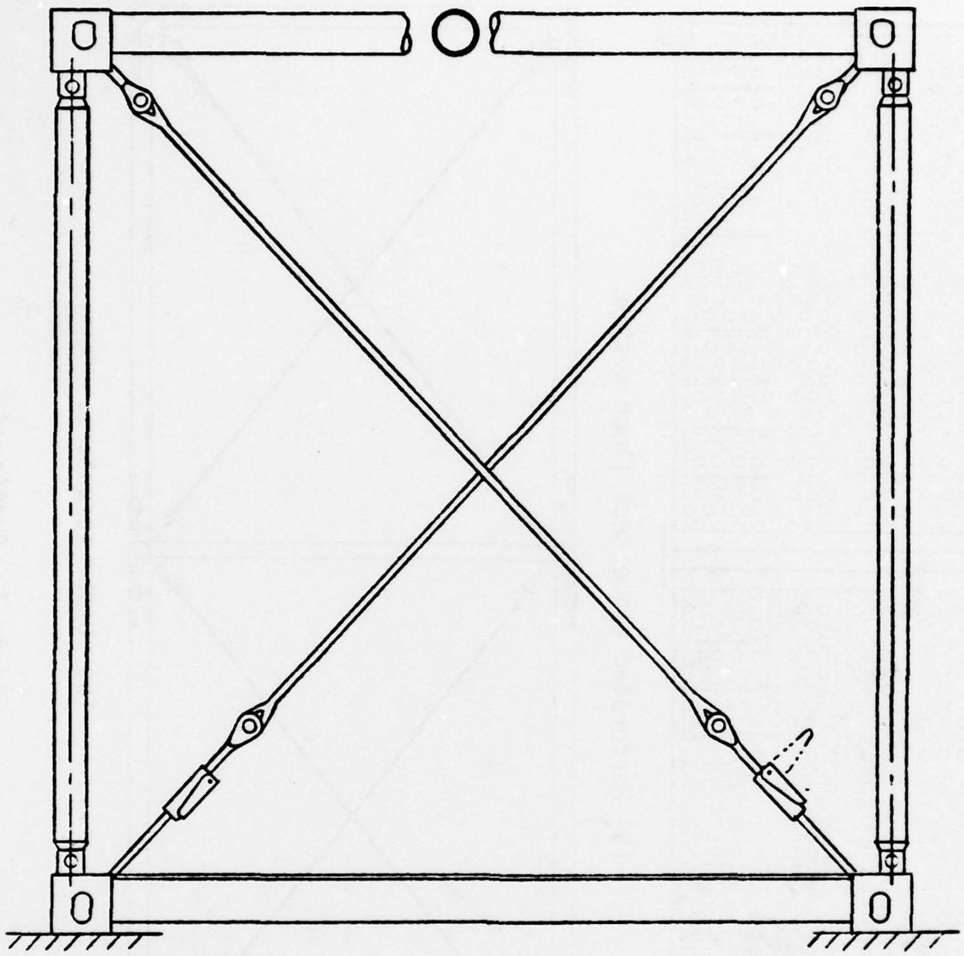
3. An ultimate longitudinal-racking load of 22.5 kips applied at an upper corner of the gondola module

4. An ultimate lateral-racking load of 22.5 kips applied at an upper corner of the gondola module.



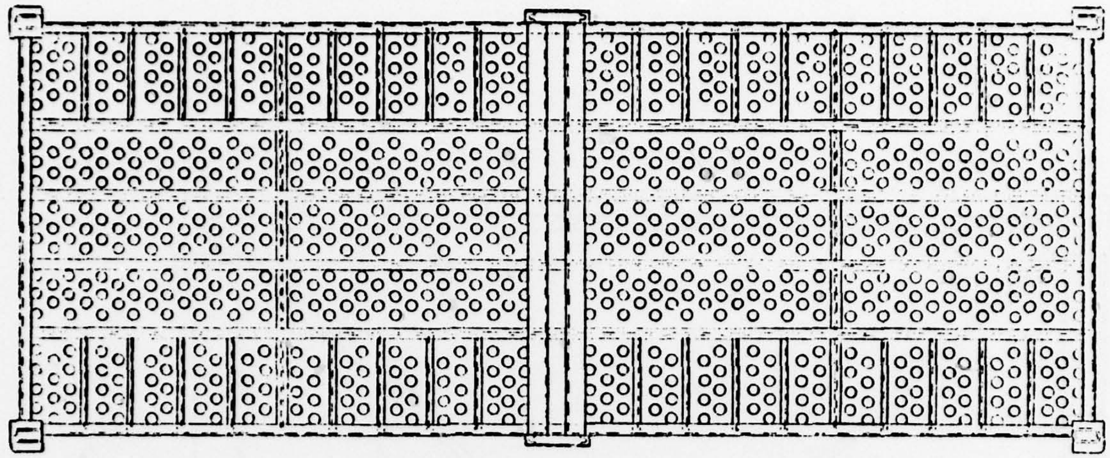
(a) Side view.

Figure 7. HEGS-20 preferred configuration.

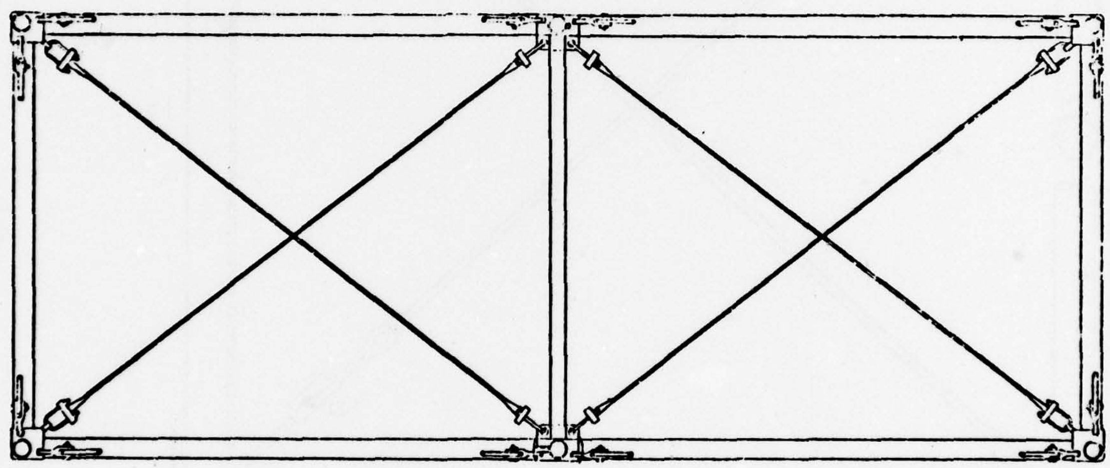


(a) End view.

Figure 7. Continued.



(a) Perforated plate deck floor system.



(b) Upper structure.

Figure 7. Continued.

The estimated cost of the HEGS-20 gondola module, shown in Figure 7, is $5,427.27 and its empty weight is 1,308.3 pounds. A breakdown of the costs and weights is shown in Table 2.

TABLE 2. COST AND WEIGHT SUMMARY FOR THE HEGS-20 MODULE

ITEM	COST (DOLLARS)	WEIGHT (LBS)
Floor Assembly	2,481.96	860.7
Upper Structure	823.32	183.1
Corner Columns	255.64	52.88
Center Columns	401.85	28.02
Diagonal Cables	829.62	36.4
Cable Attachment Hardware	546.01	108.2
Miscellaneous Attachment Hardware	17.38	39.0
Packaging	71.49	---
TOTALS	5,427.27	1,308.3

The long sides of the HEGS-20 module are subdivided and trussed to provide supports for the floor at its midspan, as well as at its ends. The trussing is accomplished by two removable center columns and pairs of removable diagonals in each panel.

Figure 8 shows the details for the removable center column. It is essentially a jack-post having an adjustable upper end. A permanently installed handle is used to permit installation or removal without tools. During installation, the lower square-ended fitting is inserted into the square hole of the lower bracket (which prevents the column from rotating) and the adjustable fitting is screwed upward until it engages the round hole in the upper bracket. Detents spaced 90 degrees apart are provided on the upper column fitting to prevent the handle from rotating during normal operations.

Other features included in the design of the center column area of the HEGS-20 module include:

1. T-bar slots are provided in the upper and lower brackets for attaching the diagonals.

2. Steps are provided on the center column to permit personnel to climb on the side of the module. It should also be noted that similar provisions will be provided on the end columns.

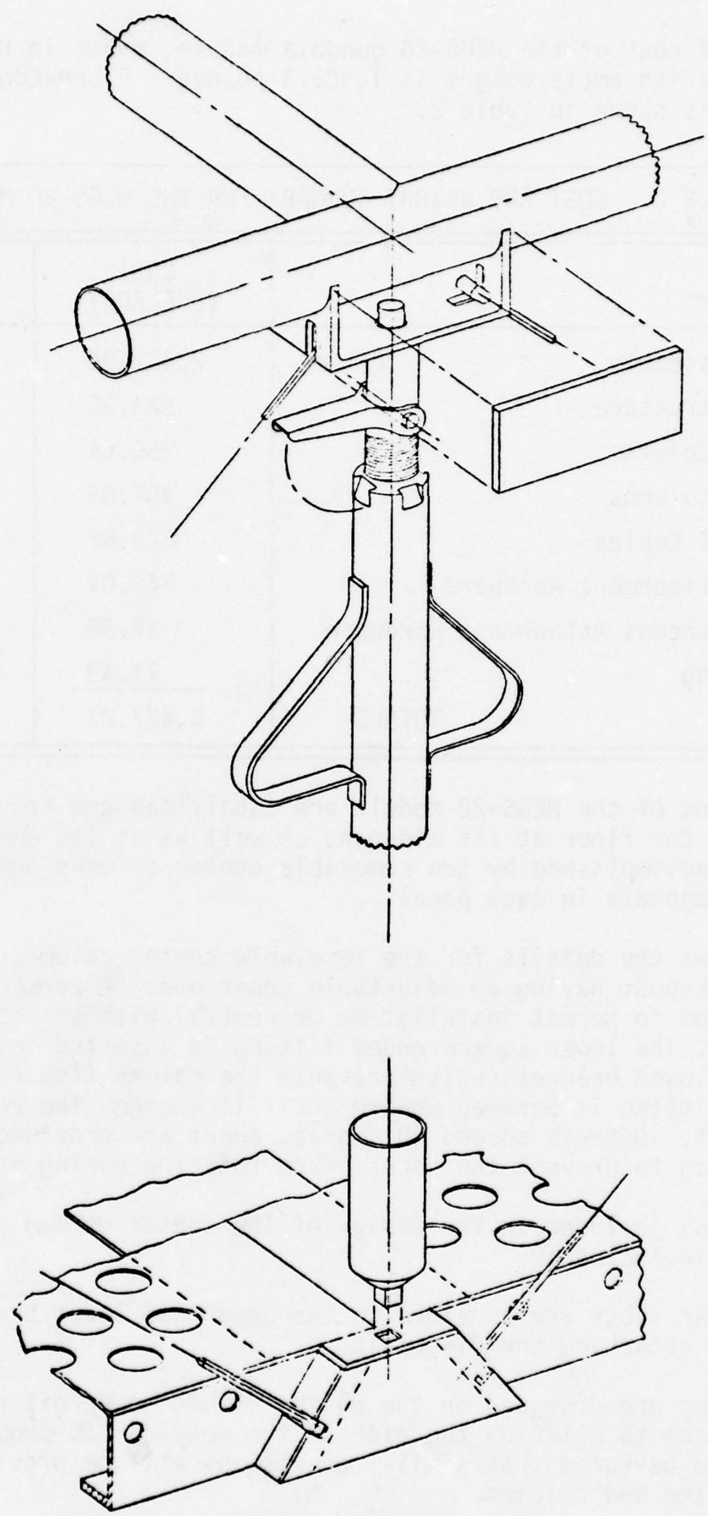


Figure 8. Removable center column.

As with the HEGS-10 module, the upper diagonals for the HEGS-20 module are shown attached to the upper frame by U-bolt diagonal end fittings. Should rapid access for loading or unloading cargo be desired through the top, T-bar diagonal end fittings may be substituted for the U-bolt end fittings with some increase in cost and weight.

HEGS-PALLETIZED GONDOLA MODULE

The preferred design for the HEGS-Palletized gondola module is shown in Figures 9 and 10. The module is approximately 20 feet long, 10 feet wide at the base, 8 feet wide at the upper surface, and 8-1/2 feet high. Its fully loaded gross weight is 25,000 pounds. The HEGS-Palletized module was designed to withstand the same loading conditions specified for the HEGS-20 module as previously defined.

The estimated cost of the HEGS-Palletized gondola module is $6,962.90 and its empty weight is 1,602.0 pounds. A cost and weight breakdown for the HEGS-Palletized module is shown in Table 3.

TABLE 3. COST AND WEIGHT SUMMARY FOR THE HEGS-PALLETIZED MODULE

ITEM	COST (DOLLARS)	WEIGHT (LBS)
Floor Assembly	3,165.96	1,097.9
Upper Structure	1,039.60	196.8
Corner Columns	767.94	105.9
Center Columns	524.90	24.4
Diagonal Cables	829.62	35.5
Cable Attachment Hardware	546.01	108.2
Miscellaneous Attachment Hardware	17.38	34.2
Packaging	71.49	---
TOTALS	6,962.90	1,602.9

Special requirements governing the design of the HEGS-Palletized gondola module are:

1. The top planform configuration shall conform with dimensional specifications for 8-foot-wide, 20-foot-long units, ANSI document MH 5.1-1971.

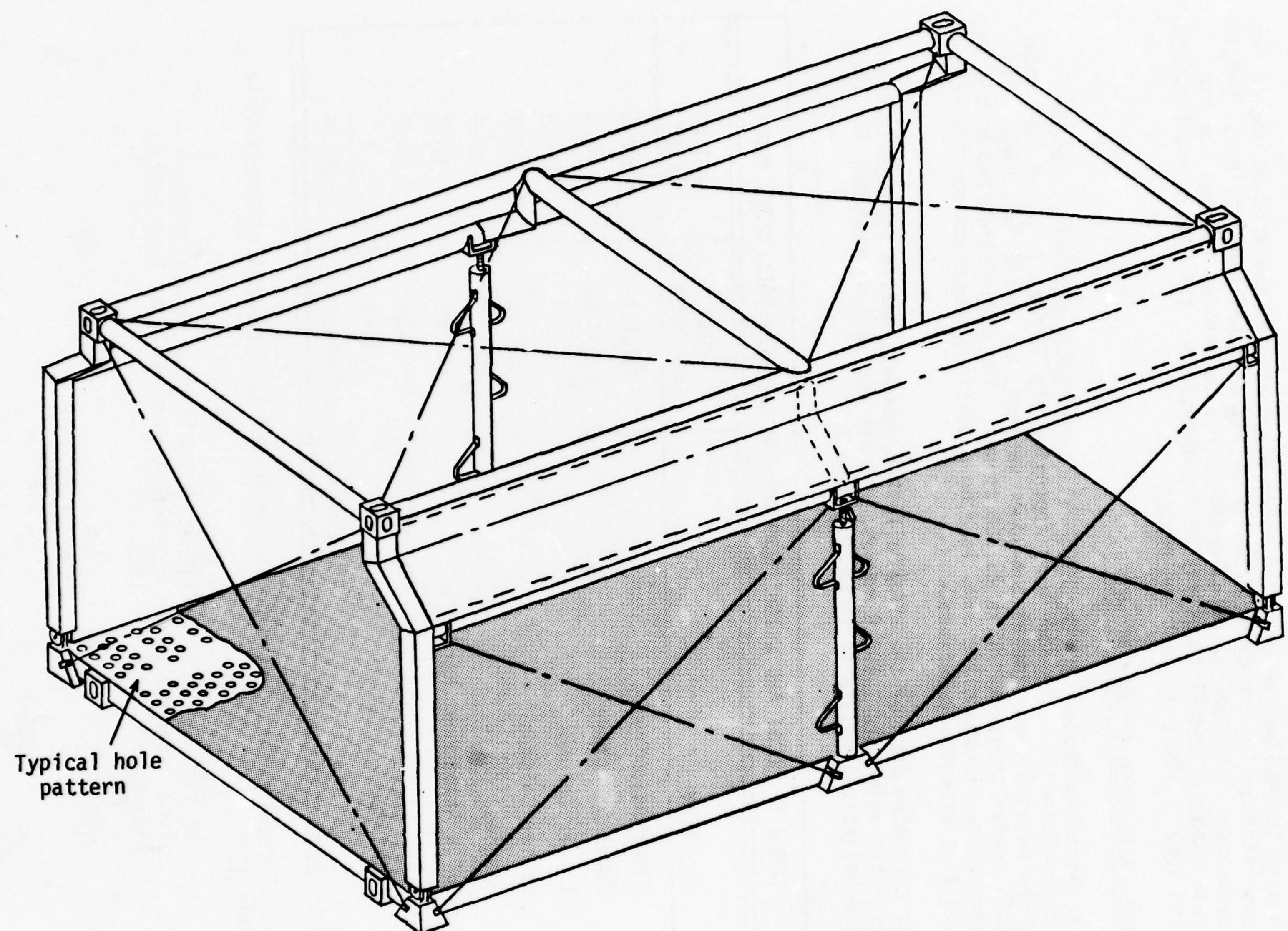
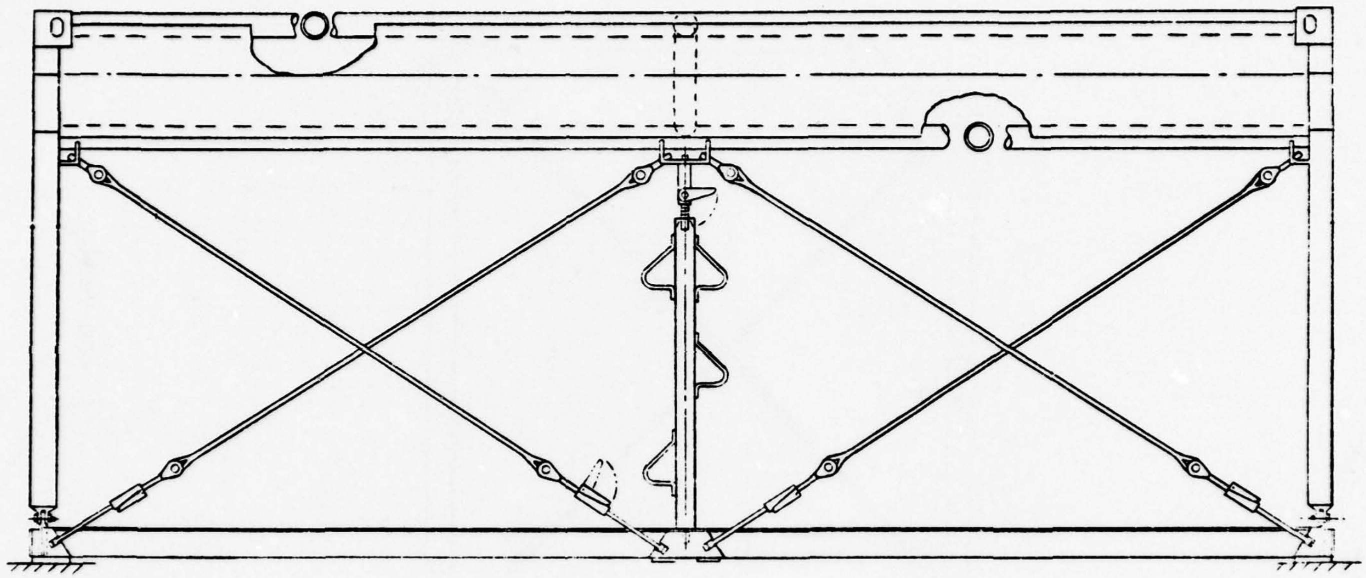
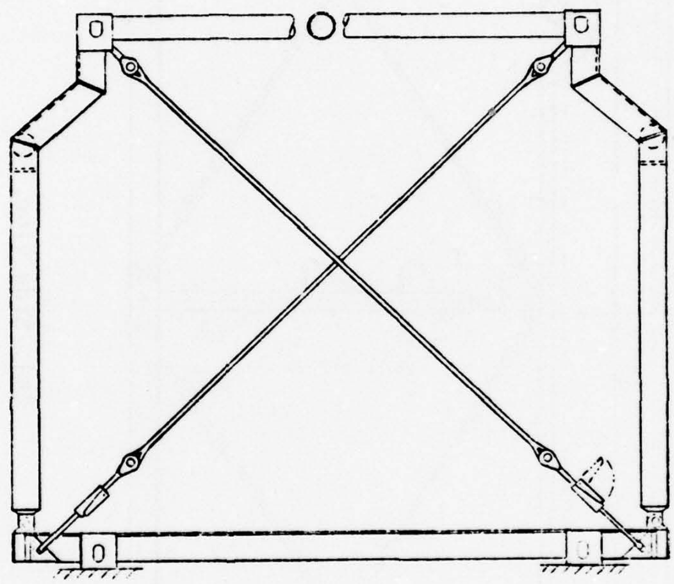


Figure 9. HEGS-Palletized preferred gondola module isometric.



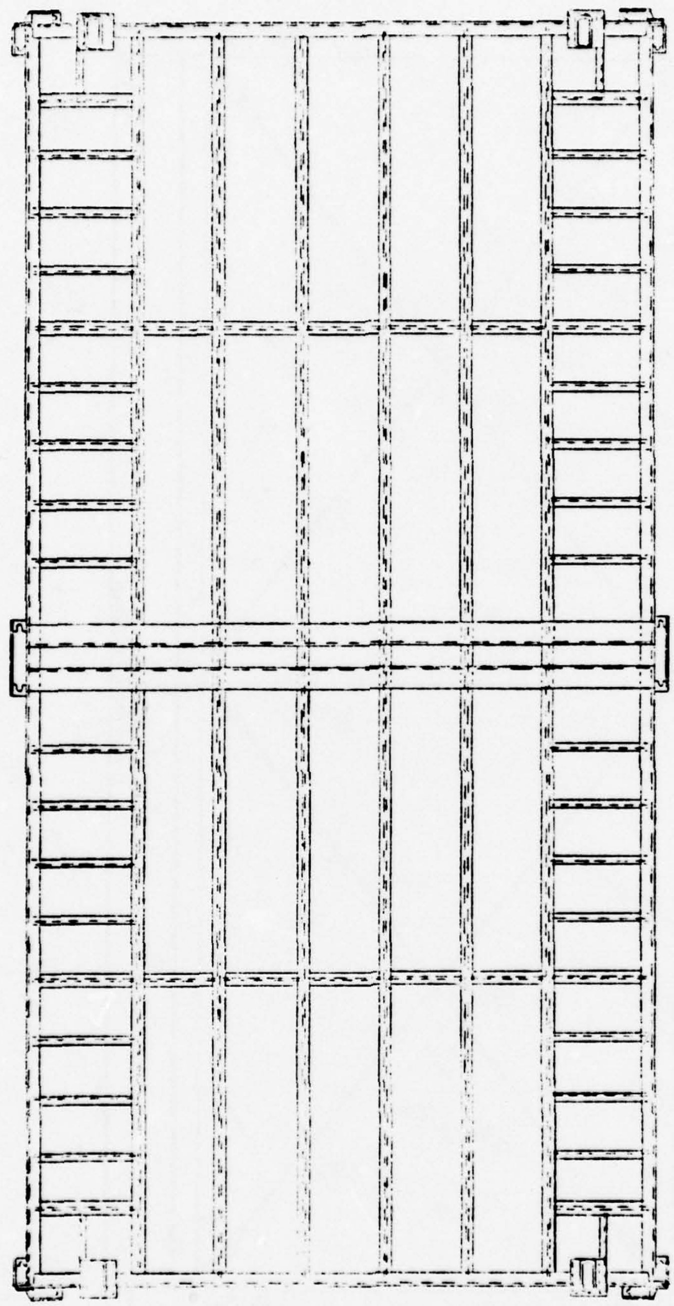
(a) Side view.

Figure 10. HEGS-Palletized preferred configuration.



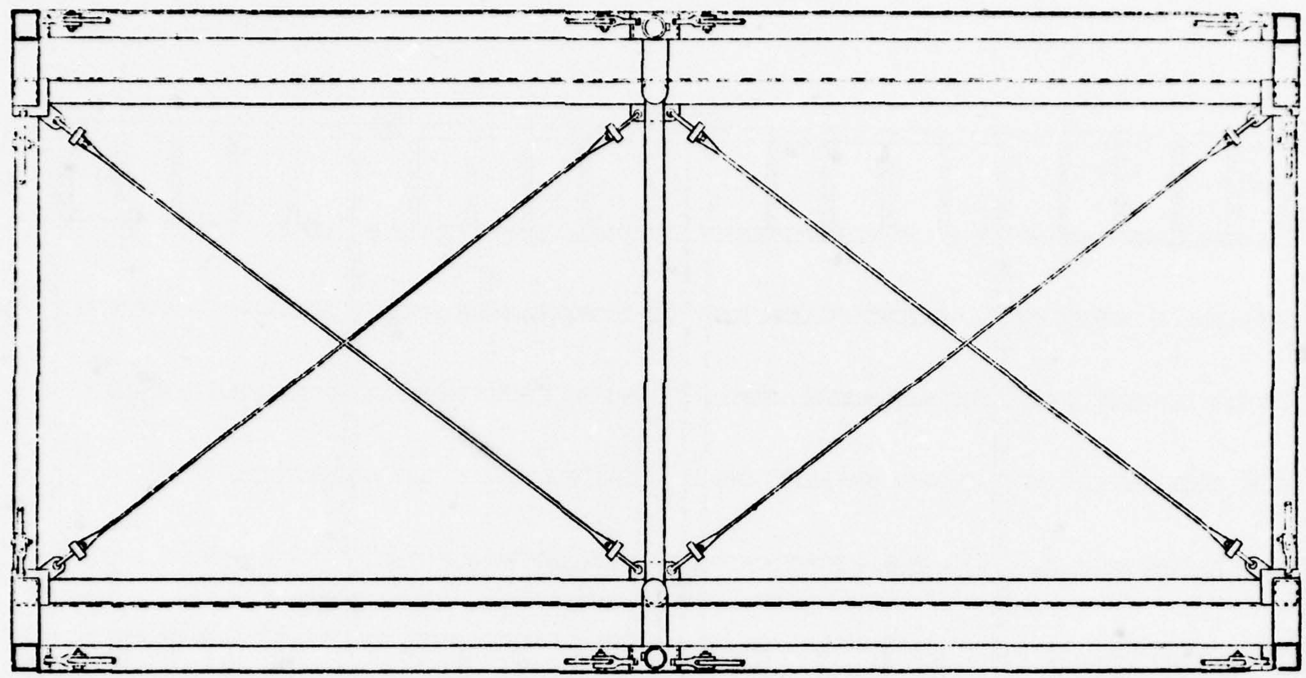
(a) End view.

Figure 10. Continued.



(a) Floor system.

Figure 10. Continued.



(a) Upper structure.

Figure 10. Continued.

2. The exterior width of the base shall be the minimum attainable consistent with an interior effective width of 110 inches + 2 inches - 0. This dimension shall be maintained for a height of 6 feet above the floor surface.

3. The exterior length of the base shall conform with dimensional specifications for 20-foot-long units, ANSI document MH 5.1-1971.

4. The bottom planform configuration (underside of the base) shall provide for attachment points that conform with dimensional specifications for 8-foot-wide, 20-foot-long units, ANSI document MH 5.1-1971.

Many of the features previously discussed for the HEGS-10 and HEGS-20 gondola modules are also applicable to the HEGS-Palletized gondola module. In view of the special requirements for this design, however, modifications must be made to the configuration of the floor, upper structure, vertical columns, and column/diagonal attachment points.

The floor system shown in Figures 9 and 10 reflects the increased width corresponding to the 110-inch minimum clear interior width requirement. Two additional longitudinal beams are used to accommodate the extra width. Auxiliary structure was also added to support the lower ISO attachment fittings which are located approximately 15 inches in from the extremities of the end beams. At each corner, slotted brackets and column attachment lugs are provided for attaching the diagonal T-bar fittings and the columns. The hole pattern used for the HEGS-Palletized module's perforated plate deck is similar to that used for the HEGS-10 and HEGS-20 decks. This feature would permit floor roller systems developed for the HEGS-Palletized modules to be used with the two other gondola systems.

In order to meet the special requirements for the HEGS-Palletized gondola modules previously defined, the upper structure and the vertical columns must be altered considerably from those required for the HEGS-20 modules. As shown in Figures 9 and 10, eccentrically loaded beam-columns are required to conform to clear width requirements for end loading, while still meeting the upper geometry requirements for 8-foot-wide units as well as the requirements for automated lifting devices. Column stability requirements in the fore and aft direction necessitate the addition of a longitudinal member at approximately 6 feet above the floor surface, a bent-up shear web, and an upper center column member for each side of the module.

As the column for the HEGS-Palletized module will be subjected to appreciable bending moments caused by the 12-inch eccentricity in addition to the normal axial loading, a substantial column is required. A 4-inch x 4-inch x 1/8-inch 6066-T6 aluminum tube, reinforced with cover plates in the area of high bending moment, was selected as being adequate for this member. The welded assembly of cover plates, lower end fittings, and of high bending moment, was selected as being adequate for this member. The welded assembly of cover plates, lower end fittings, and rectangular tubing

would be heat-treated to the T-6 condition subsequent to welding to insure high bending strength in the cover plate area. No post-weld heat would be required for the attachment of the column to the upper corner fitting. The double-lug end fitting of forged 6061-T6 welded to the lower end of the rectangular tube permits the bolted attachment of the column to the lugs mounted at the corners of the floor structure. Monoball bearings are installed in the floor-mounted corner lugs to minimize the magnitude of bending moments that could be imposed on the column due to floor deflection or warping.

The all-welded upper structure is composed of 6061-T6 aluminum tubing and sheet, and forged 6066-T6 aluminum standard ISO upper corner fittings (6-inch-diameter, .094-inch-thick tubing is used for the upper longitudinal side member and the upper lateral center members; 3-3/4-inch-diameter, .049-inch-thick tubing for the intermediate side member; and .032-inch-thick sheet for the bent-up shear webs).

A removable center jack-post is provided on each side to facilitate side loading and unloading operations and is similar to that described for the HEGS-20 module.

Diagonal T-bar attachment points are provided in the upper corner fittings, on the intermediate side member of the upper structure, and on the floor structure. Upper diagonals similar to those used for the HEGS-10 and HEGS-20 modules are provided.

Provisions incorporated in the floor system of the HEGS-Palletized gondola module that are compatible with the load/unload of the 463L pallets and the 40-inch x 48-inch cargo pallets are:

1. Uniformly spaced floor surface perforation around the periphery of the floor for attaching deck-mounted roller strips.

2. Uniformly spaced holes through the side and end floor beams for attaching off-loading roller sections that can be used for unloading cargo from the gondola floor to the surface of the ground. These holes are also used for attaching load/unload ramps.

Figures 11 and 12 show a roller system that is compatible with the perforated floor system of the HEGS-Palletized gondola module. The length of the roller strip was selected as approximately 10 feet (the width of the floor) so that it could be used either for the side loading of cargo or for the end loading of cargo by placing two strips end-to-end to extend the full length of the 20-foot-long floor. Several rows of roller strips may be placed side by side or separated as pallet size and weight dictate. For maximum load capacity, it is desirable to design the width of the roller strips such that they may be placed side by side; therefore, the width of the roller strip must be compatible with the spacing of the floor perforations.

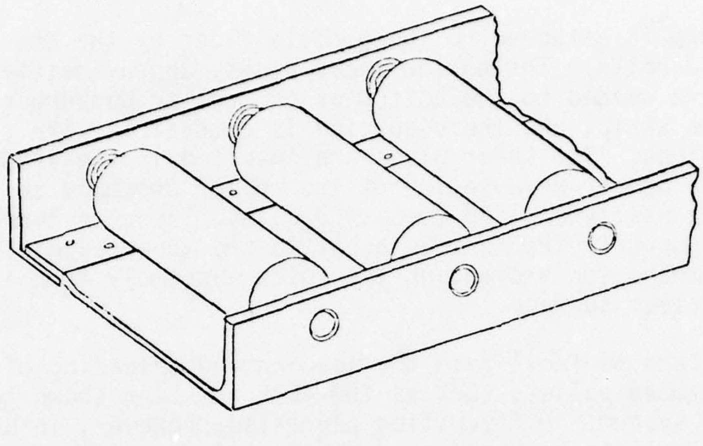


Figure 11. Ganged roller assembly.

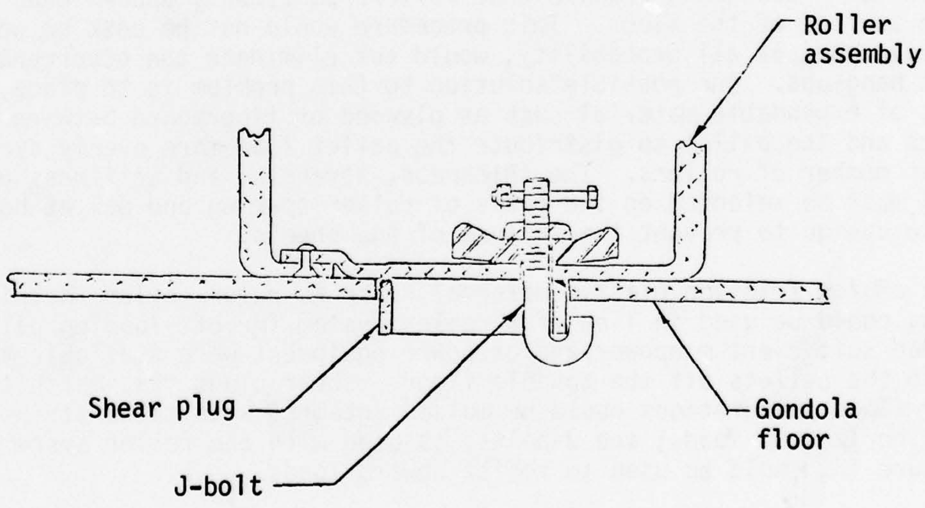


Figure 12. Roller assembly retention.

Structure supporting the individual rollers is composed of two angle-shaped sections riveted together to form a channel section. The rollers are hollow, low-cost, lightweight components formed by rotary swaging round tubes into the configuration shown.

The roller strip is attached to the gondola floor by the use of two shear plugs and two J-bolts. The hollow shear plugs, approximately 2-1/4 inches in diameter, are welded to the bottom of the roller support structure near the ends of the strip, and their spacing is compatible with the perimeter floor perforations. The shear plugs are inserted in the floor perforations to maintain the proper orientation of the roller assembly to the floor and to resist horizontally applied loads. J-bolts, inserted through the bottom of the roller support structure adjacent to the inner edge of the shear plugs, form a means for preventing the roller assembly from lifting vertically off the floor surface.

The use of rollers to facilitate the loading and unloading of smooth, flat, continuous-bottomed pallets such as the 463L has been shown to be a viable cargo handling system. Difficulties can arise, however, in using a roller system to move pallets having discontinuous bottom surfaces such as the slat-bottomed wood pallets. Hang-ups can occur when a pallet slat rolls off a roller end or a slat breaks due to a highly concentrated roller load. In general, the size, shape, and design of the wood pallets are not standardized but are tailored to accommodate the specific requirements of the cargo being carried. For those cases where mixed cargo is being transported by a gondola, the placement of rollers to effectively accommodate the various pallet sizes would require that rollers be closely spaced over the entire surface of the floor. This procedure would not be cost or weight effective and, in all probability, would not eliminate the occurrence of pallet hang-ups. One possible solution to this problem is to place flat sheets of expendable material such as plywood or fiberboard between the rollers and the pallet to distribute the pallet load more evenly over a greater number of rollers. The thickness, strength, and stiffness of these sheets must be selected on the basis of roller spacing and pallet bottom surface design to prevent the failure of the sheets.

Strips of low friction plastic material, such as rulon, nylon, delrin, or Teflon, could be used in lieu of a roller system for off-loading pallets provided sufficient manpower and/or power equipment were available to drag or push the pallets off the gondola floor. Shear plugs that match the perimeter floor perforations could be molded integral with these strips to resist horizontal loads; and J-bolts, as used with the roller system shown in Figure 12, could be used to resist upward loads.

ALTERNATE MATERIALS AND CONCEPTS

During the evolvement of the preferred gondola concepts, several alternative materials and structural configurations were considered and judged to be less beneficial than the preferred concepts. This section presents the rationale for such judgements. In general, the advantages of the preferred concepts were substantial and the selection clearcut.

MATERIALS

Reference 3 presents an evaluation of materials and methods of construction for gondolas. Their conclusion was:

> "From this material evaluation, the two candidates which offer the greatest potential are aluminum and steel. Therefore, judicious use of these materials should be considered for the framing members as a minimum. Joints and connections to minimize bulk may of necessity utilize steel members and continuous members utilize aluminum."

This conclusion has been borne out by the present study with one major exception: the use of Kevlar cables for the diagonal members.

The earlier study reached its conclusion on the basis of general comparisons of relative impact resistance, ease of joining, strength-to-weight ratios, and relative cost-to-strength ratios. In the present study, advanced configuration designs have been developed to a greater extent which allowed specific costs and weights to be identified for a family of gondolas. It has been found that the costs and weights are low and attractive. For example, the empty weight of the HEGS-10, HEGS-20 and HEGS-Palletized gondolas is only 8%, 5%, and 6%, respectively, of the loaded gondola gross weights, and the price to the Army for such gondolas will be less than $5.00 per pound of gondola structure.

The objective of this program was to develop low-cost designs which had the highest benefit-cost ratio to the Army. In simplified terms, benefit can be defined as net payload carried per trip. In general, this has meant that the designs use simple components which require almost no machining or heat-treatment to enable inexpensive fabrication. For example, members typically are of constant cross section to reduce fabrication costs. If tapered members were used, the weight of the gondolas could be reduced; however, such weight benefits would significantly increase costs and be less

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3. Weber, C., and Young, R., DESIGN CONCEPTS FOR HELICOPTER PALLETS AND GONDOLAS, Parsons of California, USAAMRDL-TR-74-91, Eustis Directorate, U. S. Army Air Mobility Research and Development Laboratory, Fort Eustis, Virginia, November 1974, AD004013.

desirable. At their present weights (5% to 8% of gross) decreases in structural weight of the gondolas provide little benefit in terms of percentage increase in payload weight. For example, even if the weight of the gondola were halved, the payload would increase by only 4.3% and 2.6%, respectively, for the HEGS-10 and HEGS-20. Thus, the most effective way to increase the benefit-cost ratio is to reduce cost.

Such benefit-cost considerations made it difficult for composites of filaments and resins to find a role in the construction of the gondola. In comparison to filamentary reinforced composites, the aluminum alloys selected for the preferred designs have the following advantages:

1. Lower cost and weight in their attachments, which are made by welding

2. Lower material cost, approximately $1.00 per pound for aluminum

3. Higher tolerance to severe impact damage and easier repairability by welding

4. Higher abrasion resistance

5. Higher environmental resistance.

The carbon/graphite reinforced composites offer both higher strength and stiffness per pound than aluminum, and thus, an opportunity to achieve lower structural weight; carbon/graphite structures, however, would be expensive. The present price for the raw materials is about $30 per pound for carbon/graphite filaments and about $40 per pound for carbon/graphite-epoxy prepregs. Even with simple, easily fabricated designs, the corresponding price to the Army for a finished gondola component will exceed $70 per pound of carbon/graphite used, which is more than 15 times the average cost per pound of the preferred concepts. Because of these higher costs, in the present study no design using carbon/graphite composites was conceived that could justify their use in gondolas. In addition to high cost, carbon/graphite-resin composites would require special protection against impact damage that must be expected in the rough transportation environment in which the gondola operates. A scheme for providing this protection by bonding the graphite to the inside of metal tubes is described later in this section. Such hybrid configurations are promising candidates for future investigation if carbon/graphite becomes available at greatly reduced prices.

Glass reinforced composites are available at prices that are competitive with aluminum. Typical present prices for the raw materials are $1.50 per pound for glass filaments and $3.00 per pound for glass-epoxy prepregs. However, the fabrication and attachment of gondola components made from glass composites would be more costly than the extruding, forging, and welding that can be used for aluminum. The price to the Army for finished

glass-filament components would be several times that of the preferred aluminum gondolas. In addition, in the present study no configuration was identified that would provide weight saving benefits.

The following list (from Reference 4) reviews and summarizes the composite materials, matrix characteristics, and fabrication methods that were considered for use in the gondola program but were adjudged to be less acceptable than welded aluminum on the basis of material and/or fabrication costs, damage resistance, repairability/maintainability requirements, and wear resistance.

Fiber Characteristics

- E-glass is the lowest cost fiber reviewed. In comparison to other fibers, it has moderate strength, low modulus, high density, good inherent damage tolerance, and moderate fatigue characteristics.

- S-glass is a relatively low cost material, approximately 2-1/2 times the cost of E-glass. The modulus of elasticity, static strength, and fatigue strength are higher, and the density is slightly lower than that of E-glass. Damage tolerance and crack propagation properties are good.

- Kevlar 29 is a moderate cost material at seven to eight times that of E-glass. The modulus of elasticity is similar to S-glass, but the density is lower than either E-glass or S-glass. Although tensile strengths are moderately high, compressive strengths are low. Fatigue properties are undocumented. Damage tolerance and crack propagation rates are similar to those of glass composites.

- Kevlar 49 is a moderate cost material at eight to nine times the cost of E-glass. The modulus of elasticity is higher than that of Kevlar 29 and the density is low, yielding a favorable stiffness/weight ratio. Tensile strength is moderate, but compressive strength is low. Damage tolerance and crack propagation characteristics are slightly lower than those of glass composites. Fatigue strength is higher than that of glass composites.

- Moderate modulus graphite is moderately high in cost at about 30 times E-glass. The modulus of elasticity is

4. Hardersen, C. H., and Blackburn, W., PRELIMINARY DESIGN STUDY OF A COMPOSITE MAIN ROTOR BLADE FOR THE OH-58 HELICOPTER, Kaman Aerospace Corporation, USARTL-TR-78-29A, Applied Technology Laboratory, U. S. Army Research and Technology Laboratories (AVRADCOM), Fort Eustis, Virginia, September 1978, AD A064159.

about three times that of S-glass and 50% greater than that of Kevlar 49. The material has substantially lower damage tolerance and crack propagation characteristics than glass composites. Tensile strength is moderate, and fatigue strength is substantially greater than that of glass composites or Kevlar.

- High modulus graphite is high in cost and has a high modulus of elasticity. Tensile strength is low, but fatigue strength is high compared to glass composites. Damage tolerance is poor.

- Boron is expensive, about 200 times the cost of E-glass. It has a high modulus of elasticity and high compressive strength.

Matrix Characteristics

- Epoxy matrices have long been used in aircraft quality structures. The processing characteristics, environmental response, and fatigue performance are well documented and, at present, they are the preferred matrix for structural applications where high strength and relibility are required.

- Polyester resin matrix fiberglass composites have been used extensively in commercial applications and in some nonstructural aircraft components, such as fairings. Their chief drawback is that their fiber/resin bonding strength, and thus their fatigue strengths, are lower than the epoxy matrices. Raw material costs are somewhat lower than the epoxies, and fabrication characteristics are better suited for the pultrusion processes.

- Polysulfone thermoplastic matrices offer promise of low-cost composite-fabrication for some structural configurations. Material fabrication characteristics are similar to epoxy prepregs. Polysulfone thermoplastics are used most advantageously in the making of formed parts from reinforced sheets. At this time, material properties have not been adequately defined to permit their use in high strength structural applications without a major material test program being conducted.

Fabrication Methods

- Filament winding is a proven, automated method for fabricating tubular structures. Low-cost raw materials such as basic fiber and resin are used.

- Braiding is promising as a high laydown rate, low-cost method of fabrication. Available equipment limits the circumference/fiber orientation obtainable. Braiding appears suitable for producing tubular members such as those used for gondola columns and upper structure. Unknown component structural properties pose a risk for production programs. Braiding appears worthy of further study and development.

- Pultrusion is attractive as a low-cost method for producing structural shapes, including tubular members. The present state of the art imposes restrictions on the section thickness, shapes, and fiber orientation attainable. Most pultrusion experience has been gained using polyester resins. The use of epoxy matrices in the pultrusion process poses risks.

- Prepreg layup is the conventional, low-risk method of composite manufacture. It appears incompatible with the low-cost goals established for the gondola program.

FLOOR CONCEPTS

Alternate concepts considered as possible gondola floor candidates were four sandwich plate floor configurations and one grated plate floor system, which are shown in Figures 13 and 14 and are described as follows:

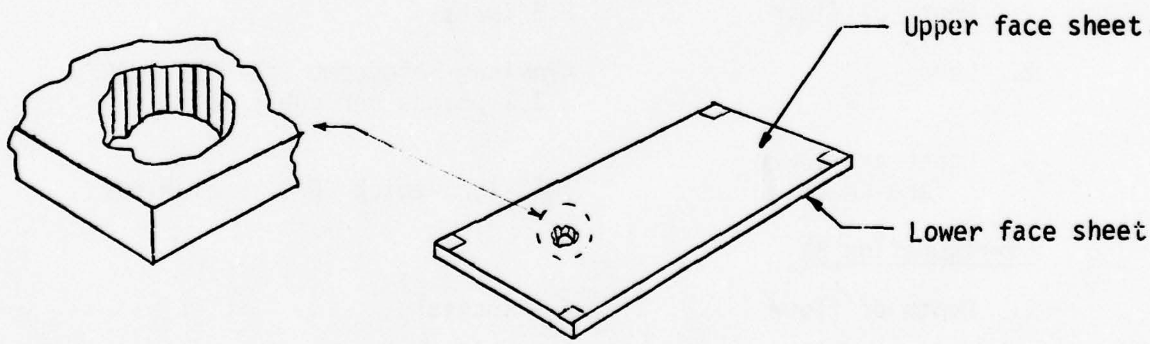


Figure 13. Sandwich plate floor system.

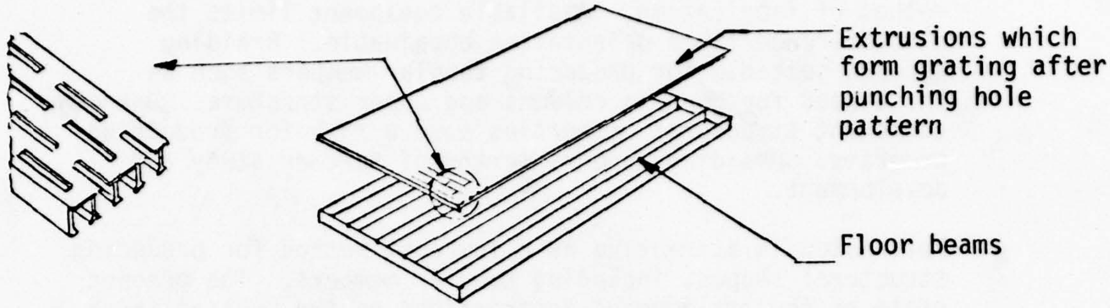


Figure 14. Grated plate floor system.

Sandwich Plate Floor Systems for the HEGS-10 Module - The sandwich floor systems consist of upper and lower face sheets separated by lightweight aluminum honeycomb core. End and side framing members were used to reinforce the perimeter of the floor and to provide a means for attaching the lower ISO corner fittings to the structure. Variations in face sheet thickness, material and separation were considered in the study. The basic parameters of the four configurations investigated were:

Configuration A:

1.	Depth of floor	2.5 inches
2.	Core	Aluminum honeycomb 1/8-5056-.0007, 3.1 pounds per cubic foot
3.	Upper and lower face sheets	.063-inch-thick 6061-T6 aluminum

Configuration B:

1.	Depth of floor	4.5 inches
2.	Core	Aluminum honeycomb 1/8-5056-.0007, 3.1 pounds per cubic foot
3.	Upper face sheet	.100-inch-thick 6061-T6 aluminum
4.	Lower face sheet	.0225-inch-thick 6061-T6 aluminum

Configuration C:

1. Depth of floor	4.5 inches
2. Core	Aluminum honeycomb 1/8-5056-.0007, 3.1 pounds per cubic foot
3. Upper face sheet	.063-inch-thick 6061-T6 aluminum
4. Lower face sheet	.035-inch-thick 6061-T6 aluminum

Configuration D:

1. Depth of floor	4.5 inches
2. Core	Aluminum honeycomb 1/8-5056-.0007, 3.1 pounds per cubic foot
3. Upper face sheet	.063-inch-thick 6061-T6 aluminum
4. Lower face sheet	.036-inch-thick 181 style glass composite

Grated Floor System

Extruded aluminum grated sections are attached to the upper surfaces of the longitudinally oriented floor beams to form the deck surface of the grated floor system. Lower ISO corner fittings are attached to the floor beam structure by welding. Components making up the floor structure are:

1. Grating	1.0-inch-thick x 2.2 pounds per square foot 6061-T6 aluminum
2. Floor beams	5456-H111 aluminum extrusions

As shown in Table 4, the weights of the sandwich plate floor configurations (excluding the weight of the four lower ISO corner fittings) are competitive with the weight of the perforated orthotropic floor system. The perforated orthotropic floor system, however, was selected as the preferred floor design for the following reasons:

1. Aerodynamic stability requirements rule out the use of the solid surface of the sandwich plate floor configurations.

2. The relatively thin solid face sheets of the sandwich plate floor configurations are more damage prone and are much more difficult to repair.

TABLE 4. WEIGHT COMPARISON OF ALTERNATE FLOOR SYSTEMS FOR THE HEGS-10 MODULE	
FLOOR SYSTEM	WEIGHT, EXCLUDING CORNER FITTINGS (POUNDS)
Perforated Orthotropic Plate Deck	392
Sandwich Plate Floor Systems	
Configuration A	375
Configuration B	407
Configuration C	383
Configuration D	373
Grating Plate Floor Structure	552

3. Undetectable core corrosion due to entrapped moisture can reduce the strength capabilities of sandwich plate structure.

4. The local overload capacity of the perforated orthotropic plate floor system is superior to that of the sandwich plate floor configuration which can fail by core crushing and face sheet-to-core delamination.

The perforated orthotropic plate floor system was selected over the grated floor system because conventional grating supported by an under-structure of floor beams is considerably heavier than the perforated orthotropic floor system, and it does not possess the omnidirectional strength that is desirable for dragging heavy loads across the surface.

TUBE CONCEPTS

Aluminum tubing was used for the columns and the upper structure of the three preferred gondola module concepts because of its low cost, ease of fabrication, and high impact resistance. In many of the tubes analyzed in Appendix A, the section properties, and thus the weight, were dictated by buckling considerations. An alternate concept, designed to reduce the buckling criticality and also the weight, utilized a thin-walled aluminum tube reinforced in the buckling area by an inner sleeve of carbon/graphite. The tube ends were also locally reinforced by welding thicker aluminum rings to each end of the tube to provide adequate strength after welding of the lug fittings to the tube without post-weld heat-treatment.

Figure 15 presents the basic details of this configuration, and Appendix A presents the structural analysis of an aluminum-carbon/graphite tube sized for the HEGS-20 corner column. The results of this analysis indicate that the weight of the tubular portion of the column could be reduced from 11.6 pounds for the preferred all-aluminum tube to 6.5 pounds for the aluminum-carbon/graphite tube, thus providing a weight savings of 5.1 pounds per column or 20.4 pounds per module. This weight savings would be approximately .08% of the design operating gross weight of the HEGS-20 module.

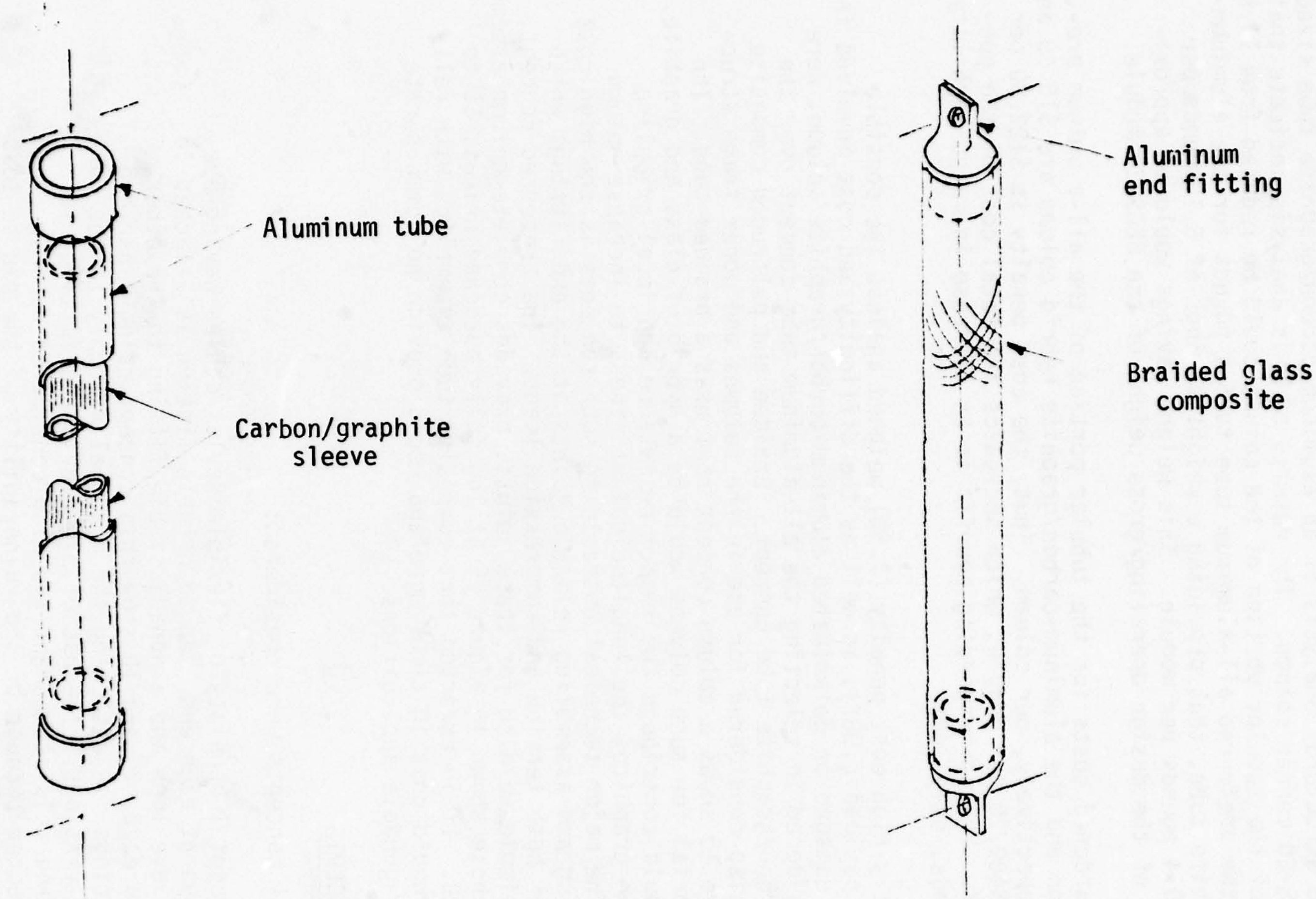
The fully burdened costs for the tubular portion of the all-aluminum preferred column and the aluminum-carbon/graphite hybrid column are $15.50 and $117.80, respectively, per column. Thus, the cost penalty is $102.30 per column and $409.20 per module, which increases the total cost of the gondola by 7.5%. The corresponding benefit is an increase in cargo capbility of 20.4 pounds, only .08%.

The relatively high cost penalty (7.5%) weighed against the possible increase in payload (.08%), as well as the difficulty and cost involved in repairing a damaged or delaminated aluminum-carbon/graphite column, were factors considered in selecting the all-aluminum tube concept over the aluminum-carbon/graphite tube concept. Braided and pultruded composite tubes were also considered for use in the columns and upper frame structure. Figure 15 shows a column concept that uses a braided tube. The optimum material for such columns would be a hybrid of glass and graphite. The glass would contribute the impact resistance and local crippling strength; the graphite, the longitudinal stiffness to increase column strength. The major technical obstacle to such concepts is the high cost of fabricating and assembling reliable joints at the end fittings which must transfer both tension and compression loads. The preferred concept, which uses simple welding for these joints, provides complete column assemblies like those shown in Figure 15 at low fully burdened prices, $5 to $11 per pound. It is expected that composite tube assemblies with reliable joints would cost 10 times more and could provide no commensurate benefits for gondola applications.

DIAGONAL CONCEPTS

Four diagonal concepts were considered:

1. Concept I consists of flexible Kevlar cables having eye loops at each end. An adjustable fitting is attached to one eye loop and a nonadjustable fitting to the other. Figures 2, 7, and 10 show this concept using T-bar end fittings for attaching the diagonal assembly to the corner fittings. The use of pin-clevis end fittings for making this attachment was also considered but was rejected because of the vulnerability of the pin to loss or damage.



(a) Aluminum-carbon/graphite tube.

(b) Braided column

Figure 15. Alternate tube concepts.

2. Concept II is similar to Concept I, but semirigid steel cable is used in place of the Kevlar cable.

3. Concept III consists of a rigid necked-down steel rod threaded on one end to receive the adjustable fitting and welded to a nonadjustable T-bar fitting at the other end, as shown in Figure 16.

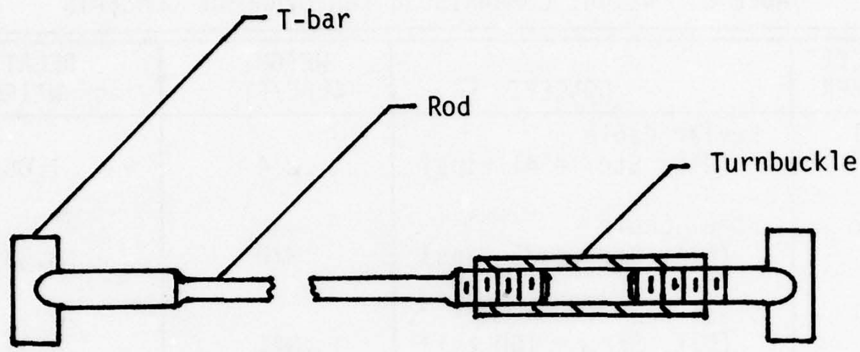


Figure 16. Steel rod diagonal concept.

4. Concept IV considered the use of a rigid thin-walled aluminum tube to which steel end fittings were swaged to accommodate the adjustable and nonadjustable end fittings as shown in Figure 17.

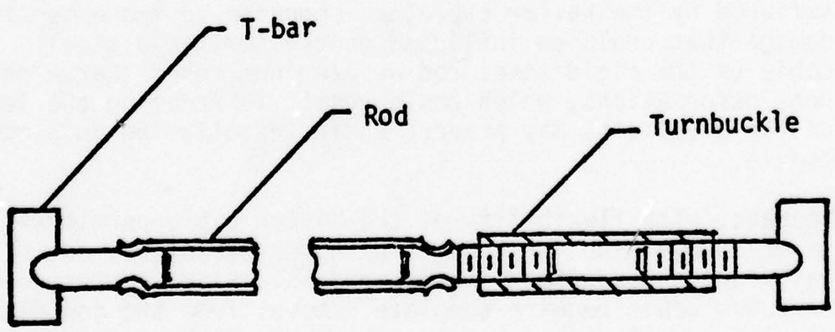


Figure 17. Aluminum tube diagonal concept.

Table 5 presents a weight comparison of the Kevlar cable, steel cable, steel rod, and aluminum tube portion of the diagonal assembly. The weight per foot of cable, rod, or tube required to resist an ultimate load of 32.8 kips (maximum ultimate diagonal load for the HEGS-20) is shown, as well as the relative weights of the steel cable, steel rod, and aluminum tube compared to the weight of the Kevlar cable.

TABLE 5. WEIGHT COMPARISONS FOR DIAGONAL CONCEPTS

CONCEPT NUMBER	CONCEPT	WEIGHT (LBS/FT)	RELATIVE WEIGHT
1	Kevlar Cable (Ult. Str. = 41 kips)	.214	1.00
2	Steel Cable (Ult. Str. = 35 kips)	.820	3.83
3	Steel Rod (Ult. Str. = 160 ksi)	.841	3.93
4	Aluminum Tube (Ult. Str. = 58 ksi)	.906	4.23

Factors influencing the decision to select the Kevlar cable as the preferred diagonal concept included:

1. Damage Susceptibility. The relatively high flexibility of the Kevlar cable reduces its susceptibility to handling damage such as could be caused by vehicular traffic or by dropped cargo. Only minor kinks or deformations would be suffered by the Kevlar cable, as compared to the extensive damage that could be inflicted on the semirigid steel cable or the rigid steel rod or aluminum tube. Large permanent deformations, which could result in reducing the lengths of the diagonals, may prevent their installation on a gondola module.

2. Storage. The flexibility of the Kevlar cable permits it to be wrapped around the columns or upper structure, out of the way, during cargo handling operations. Stiff cables, rods, or tubes would require complete removal from the gondola module and, if placed on the ground, would be exposed to possible damage.

3. Weight. The weight of the Kevlar cable is approximately 25% the weight of the steel cable, steel rod, or aluminum tube.

CONCLUSIONS

1. The new gondolas are structurally efficient, readily producible, and operationally suitable.

2. The gondola weight is a small fraction of the loaded gross weight. The gondola weight, loaded gross weight, and gondola weight as a percentage of the loaded gross weight are:

HEGS-10	602.2 pounds, 8,000 pounds, 7.5%
HEGS-20	1,308.3 pounds, 25,000 pounds, 5.2%
HEGS-Palletized	1,602.9 pounds, 25,000 pounds, 6.4%

3. The use of low-cost materials, structurally efficient configurations, and low-cost fabrication techniques contribute to the following low initial acquisition prices:

HEGS-10	$2,971.24 per gondola
HEGS-20	$5,427.27 per gondola
HEGS-Palletized	$6,962.90 per gondola

The above prices include all recurring costs, all overheads, and a 10% profit.

4. The operational suitability of the gondolas is fostered by the following characteristics of the new designs: good aerodynamic stability, high impact resistance, high wear resistance, high environmental stability, ease of repairability and maintainability, rapid load and unload capability, multipurpose versatility, compatibility with Army cargo and utility helicopters, and compatibility with automated lifting devices and ground transport equipment.

5. The preferred constructions and materials for the major components are:

Floor	Perforated, orthotropic plate deck of 5456 aluminum alloy, welded
Columns	Tubing and forgings of 6061-T6 and 6066-T6 aluminum alloys, welded
Upper Frame	Tubing of 6061-T6 aluminum alloy, welded
Corner Fittings	Forgings of 6066-T6 aluminum alloy, welded

Adjustable Fittings	Forgings of 17-4PH corrosion-resistant steel and naval brass
Diagonals	Eyed cables of Kevlar

6. At the present low structural weight of the gondolas (5.2% to 7.5% of the loaded gross weight), decreases in structural weight provide marginally small benefit in terms of increased payload weight. Thus, the most effective way to increase the benefit-cost ratio is to reduce cost.

RECOMMENDATIONS

It is recommended that the development of the gondola concept be continued in the following steps:

1. Perform a detailed design and prepare fabrication drawings for one or more of the three preferred gondola configurations (HEGS-10, HEGS-20, or HEGS-Palletized). Selection of configuration should be governed by Army operational requirements and budgetary constraints.

2. Perform laboratory tests to assist in development of optimal components. Candidates for such test development include:

   a. End loop of the Kevlar diagonals

   b. Corner fittings

   c. The pattern of holes in the deck floor.

3. Fabricate several gondolas for testing.

4. Perform laboratory testing to demonstrate structural integrity of the gondola assembly.

5. Perform in-field service testing and user validation.

6. Perform wind tunnel testing and analysis to complement and supplement in-field service evaluations of aerodynamic stability boundaries.

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6. Harvey Report No. 335, PROPERTIES OF 6066 ALLOY, Harvey Aluminum Sales, Inc., Torrance, California, 15 October 1959.

7. Military Standardization Handbook, METALLIC MATERIALS AND ELEMENTS FOR AEROSPACE VEHICLE STRUCTURES, MIL-HDBK-5B, U. S. Government Printing Office, Washington, D. C., 1 September 1971.

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APPENDIX A

STRUCTURAL ANALYSIS

SUMMARY

The structural analysis is summarized on Table A-1, which presents minimum margins of safety for the individual members making up the structure for the HEGS-10, HEGS-20, and HEGS-Palletized gondola modules. The margin of safety is defined as: $MS = \frac{\text{Allowable Stress or Load}}{\text{Actual Stress or Load}} - 1$.

TABLE A-1. MINIMUM MARGINS OF SAFETY

GONDOLA MODULE	MEMBER	CRITICAL AREA	TYPE OF STRESS	MARGIN OF SAFETY
HEGS-10	Floor	Edge Beam	Yield Ten.	.01
	Columns	Tube Ends	Ult. Ten.	.14
	Column Bolts	Bolt Shank	Ult. Bend.	.43
	Corner Fitting Lug	Bolt Hole	Ult. Bear.	3.88
	Upper Sides	Tube Center	Ult. Buck.	.49
	Upper Ends	Tube Center	Ult. Buck.	.38
	Diagonal Cable	Side Diagonal	Ult. Ten.	.07
HEGS-20	Floor	Center Beam	Yield Ten.	.05
	End Columns	Tube Center	Ult. Buck.	.06
	Column Bolts	Bolt Shank	Ult. Bend.	.21
	Corner Fitting Lug	Bolt Hole	Ult. Bear.	1.81
	Center Column	Tube Center	Ult. Buck.	.15
	Upper Side	Tube Center	Ult. Comp.	.13
	Upper End	Tube Ends	Ult. Comp.	.64
	Diagonal Cable	End Diagonals	Ult. Ten.	.26
HEGS-Palletized	Floor	1/4-Span Beam	Yield Ten.	.04
	Corner Columns	Tube Center	Ult. Bend.	.06
	Column Bolts	Bolt Shank	Ult. Bend.	.21
	Corner Fitting Lug	Bolt Hole	Ult. Bear.	1.81
	Center Column	Tube Center	Ult. Buck.	.13
	Upper Side	Tube Center	Ult. Comp.	.13
	Upper End	Tube End	Ult. Comp.	.64
	Intermediate Side	Tube End	Ult. Comp.	.22
	Shear Web	Center Sheet	Ult. Buck.	1.65
	Diagonal Cable	Side Diagonal	Ult. Ten.	.47

INTRODUCTION

The loads and stresses acting on the three preferred cable-truss gondola module configurations were determined by the use of several analytical methods to insure that the selected designs would be structurally efficient and adequate.

NASTRAN analyses were used in designing the floor structure of each configuration. These analyses involved the iteration of several selected designs to arrive at an optimized structure having approximately equal margins of safety throughout the floor system. Component loads, stresses, margins of safety, and structure deformations are obtained as output from these programs.

A three-dimensional finite element computer program was used to determine the loads acting on the components of the superstructure of the gondola for the single-point and for the two-point suspension conditions. Component loads for the racking and stacking conditions were obtained using the conventional idealizations for analyzing cargo containers. The individual components of the superstructure were sized for the highest of the suspension, racking, or stacking conditions.

MATERIAL PROPERTIES

This section lists the material properties used in the structural analysis.

1. 6061-T6 Aluminum Alloy (Reference 5)

		TUBING AND PLATE		FORGINGS	
		BASIC	AS WELDED	BASIC	AS WELDED
F_{tu}	(ksi)	42	24	38	24
F_{cu}	(ksi)	42	24	38	24
F_{ty}	(ksi)	35	20	35	20
F_{cy}	(ksi)	35	20	36	20
F_{su}	(ksi)	27	15	25	15
F_{sy}	(ksi)	20	12	20	12
F_{bru}	(ksi)	88	50	61 - 76	50
F_{bry}	(ksi)	56	30	54 - 61	30
E	(ksi)	10100	10100	9[illegible]0	10100

2. 5456 Aluminum Alloy (Reference 5)

		H111 EXTRUSIONS		H116 PLATE	
		BASIC	AS WELDED	BASIC	AS WELDED
F_{tu}	(ksi)	42	41	46	42
F_{cu}	(ksi)	42	41	46	42
F_{ty}	(ksi)	26	24	33	26
F_{cy}	(ksi)	22	22	27	24
F_{su}	(ksi)	25	24	27	25
F_{sy}	(ksi)	15	14	19	25
F_{bru}	(ksi)	82	82	87	84
F_{bry}	(ksi)	44	38	56	38
E	(ksi)	10400	10400	10400	10400

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3. 6066-T6 Aluminum Alloy (Reference 6)

		BASIC		AS WELDED
F_{tu}	(ksi)	58		59% Efficiency
F_{ty}	(ksi)	52		
F_{cy}	(ksi)	52		
F_{su}	(ksi)	34		
F_{bry}	(ksi)	70	e/D = 1.5	
F_{bru}	(ksi)	78	e/D = 1.5	
E	(ksi)	10000		

4. 17-4PH Condition H1025 Stainless Steel (Reference 7)

F_{tu}	(ksi)	155
F_{ty}	(ksi)	145
F_{su}	(ksi)	90
E	(ksi)	28500

5. Naval Brass (Reference 8)

		ANNEALED	1/2 HARD
F_{tu}	(ksi)	57	75
F_{ty}	(ksi)	25	53
F_{su}	(ksi)	34	45
E	(ksi)	15000	15000

6. Harvey Report No. 335, PROPERTIES OF 6066 ALLOY, Harvey Aluminum Sales, Inc., Torrance, California, 15 October 1959.

7. Military Standardization Handbook, METALLIC MATERIALS AND ELEMENTS FOR AEROSPACE VEHICLE STRUCTURES, MIL-HDBK-5B, U. S. Government Printing Office, Washington, D. C., 1 September 1971.

8. 1979 MATERIALS SELECTOR, Materials Engineering, P. O. Box 91368, Cleveland, Ohio, December 1978.

6. Kevlar Cable (Reference 9)

CONSTRUCTION	DIAMETER (in.)	MINIMUM BREAK STRENGTH (ksi)	WEIGHT/FOOT (lbs)
6 x 19	.45	17.5	.048
6 x 19	.51	22.0	.072
6 x 19	.58	30.0	.095
6 x 19	.67	36.0	.115
6 x 19	.70	42.0	.135
6 x 37	.85	55.0	.186
6 x 37	.93	66.0	.223
6 x 37	1.00	77.0	.260

7. Thornel 300/Narmco 5209, Carbon Fiber Prepreg System (Reference 10)

F_{tu}	(ksi)	196
F_{cu}	(ksi)	200
F_{su}	(ksi)	16.4
E	(ksi)	19400
Density	(psi)	.056
Thickness/Ply	(in.)	.00578

9. Phillystran Technical Bulletin No. 113C, PHILLYSTRAN ROPES AND CABLES, Philadelphia Resins Corporation, 20 Commerce Drive, Montgomeryville, Pennsylvania, April 1977.

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DESIGN CONDITIONS

FLOOR

The floor beams are designed to support an off-center load which exerts 300 psf at 1-g. The centroid of the load lies at the geometrical 60% position of the floor in longitudinal and lateral directions as shown in Figure A-1. In subsequent descriptions, this is referred to as the 60/40 floor load distribution requirement.

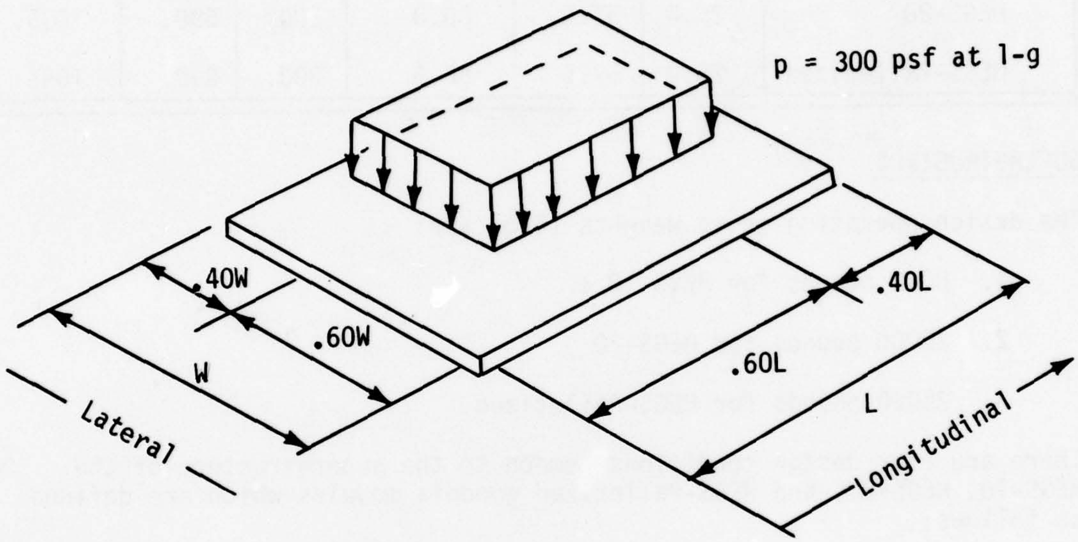

Figure A-1. Typical 1-g floor loading.

The design limit load factors (Reference 11) are:

a. 3.2 for the HEGS-10

b. 2.3 for the HEGS-20

c. 2.3 for the HEGS-Palletized.

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11. Army Regulation AR70-47, ENGINEERING FOR TRANSPORTABILITY, APPENDIX D, CRITERIA FOR AIR TRANSPORT AND AIR DROP, Headquarters, Department of the Army, Washington, D. C., 28 January 1976.

The design ultimate load is 1.5 times limit load. The corresponding design loads (kips) and load intensities (psf) for each gondola type are shown in Table A-2.

TABLE A-2. FLOOR LOADS AND INTENSITIES

GONDOLA TYPE	DESIGN FLOOR LOADS, kips			DESIGN INTENSITIES, psf		
	1-g	LIMIT	ULTIMATE	1-g	LIMIT	ULTIMATE
HEGS-10	8.0	25.6	38.4	300.	960.	1440.
HEGS-20	25.0	57.5	86.3	300.	690.	1035.
HEGS-Palletized	25.0	57.5	86.3	300.	690.	1035.

SUPERSTRUCTURE

The design operating gross weights (1-g) are:

1. 8000 pounds for HEGS-10
2. 25000 pounds for HEGS-20
3. 25000 pounds for HEGS-Palletized.

There are four design conditions common to the superstructure of the HEGS-10, HEGS-20, and HEGS-Palletized gondola modules which are defined as follows:

1. Single-Point Suspension Condition -

   a. Limit lift load factor for the HEGS-10 is 3.2.

   b. Limit lift load factor for the HEGS-20 and HEGS-Palletized is 2.3.

   c. Longitudinal and lateral position of the center of gravity is located in accordance with the 60/40 floor load distribution requirement.

   d. Vertical center of gravity is located at 12 inches and 24 inches above the floor surface.

   e. Maximum sling angle measured from a perpendicular to the floor is 30°.

2. Two-Point Suspension Condition, HEGS-10 -

a. Limit lift load factor is 3.2.

b. Longitudinal and lateral center of gravity is located in accordance with the 60/40 floor load distribution requirement.

c. Vertical center of gravity is located at 12 inches and 24 inches above the floor surface.

d. The height of the suspension points above the gondola is dependent on the following:

(1) The distance between the two suspension points is 13 feet (CH-47D cargo hook spacing).

(2) The two suspension points are symmetrical to the longitudinal centerline of the gondola.

(3) The plane of the suspension points and the plane of the gondola sling attachment points are parallel and horizontal.

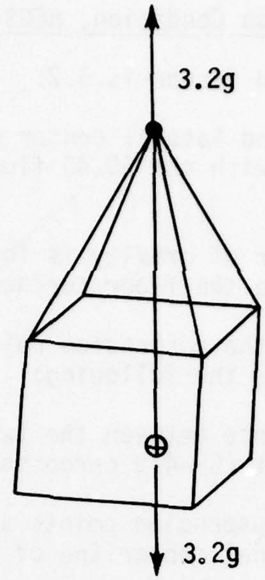
(4) The maximum sling angle measured from a perpendicular to the floor is 30 degrees.

e. The load reaction line passes through the forward suspension point, the line drawn between the two forward gondola sling attachment points, and the center of gravity of the loaded gondola. This results in the total load being carried by the two forward slings.

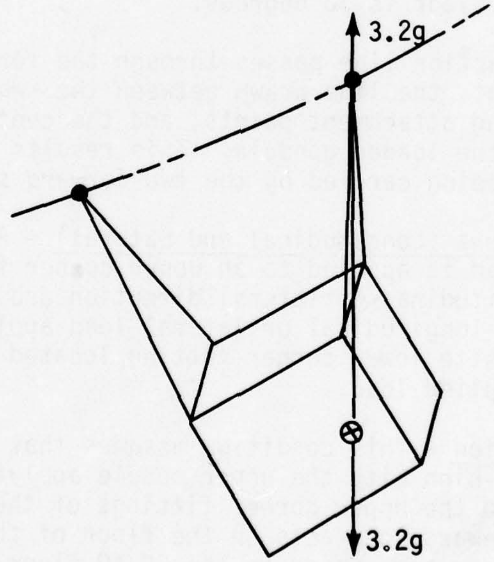
3. Racking Conditions (Longitudinal and Lateral) - A .6-g horizontal limit load is applied to an upper corner fitting in either the longitudinal or lateral direction and is resisted by a horizontal longitudinal or lateral load applied at the diagonally opposite lower corner fitting located in the same plane as the applied load.

4. Stacking Condition - This condition assumes that the modules are stacked two-high with the upper module applying a 1.8-g downward load to the upper corner fittings of the lower module while a 1-g downward load acts on the floor of the lower module. The loads correspond to the 60/40 floor load distribution requirement.

The design loading conditions for the HEGS-10 are summarized in Figures A-2, A-3, and A-4. Figure A-3 also establishes the nomenclature for the

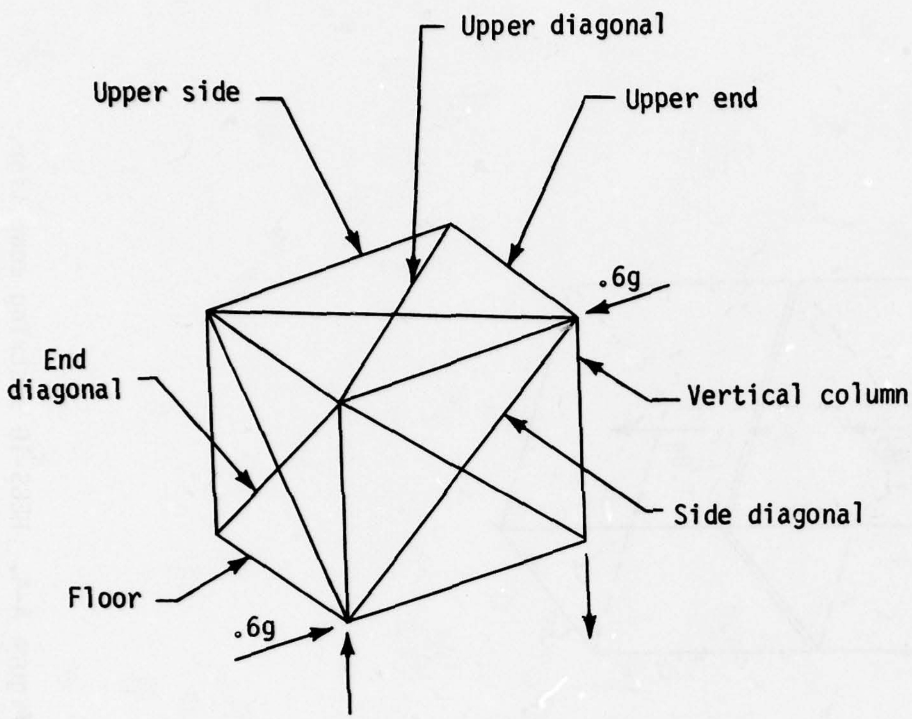


(a) Single-point suspension.

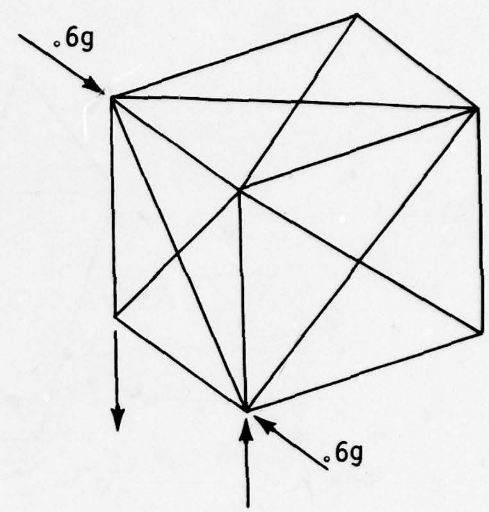


(b) Two-point suspension.

Figure A-2. HEGS-10 suspension conditions.



(a) Longitudinal racking.



(b) Lateral racking.

Figure A-3. HEGS-10 .6g racking conditions.

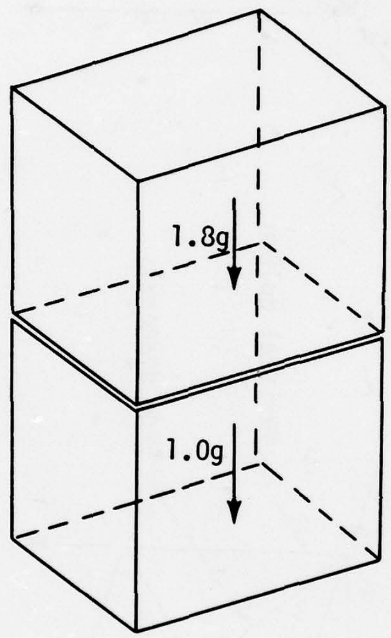


Figure A-4. HEGS-10 stacking condition.

subsequent stress analyses of the superstructure components. Corresponding data are shown for the HEGS-20 in Figures A-5, A-6 and A-7 and for the HEGS-Palletized in Figures A-8, A-9, and A-10.

Tables A-3, A-4, and A-5 present the maximum limit suspension, racking, and stacking loads acting on the individual members of the superstructure for the HEGS-10, HEGS-20, and HEGS-Palletized modules, respectively. Suspension loads were obtained from the finite element program, and racking and stacking loads were obtained by standard analyses. Table A-6 presents a summary of the maximum tension and compression loads used to size the individual members of the superstructure for the three gondola module configurations.

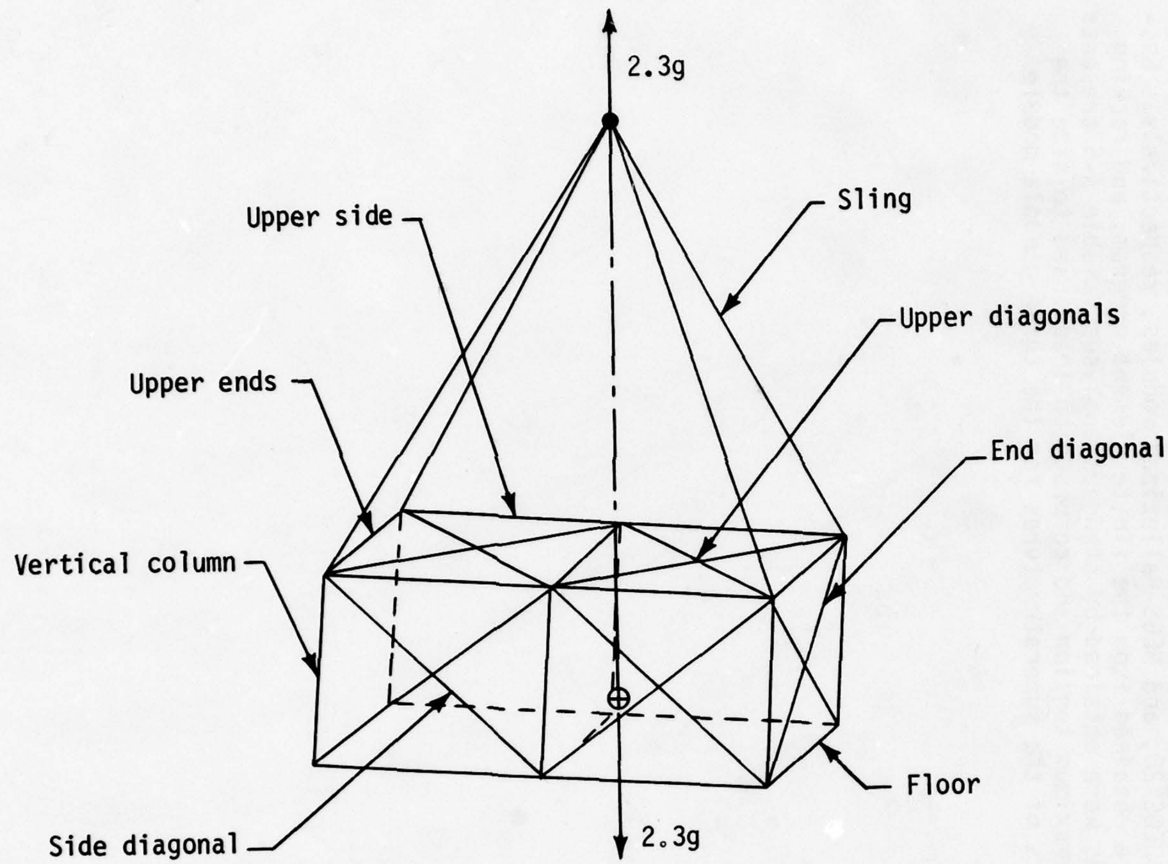
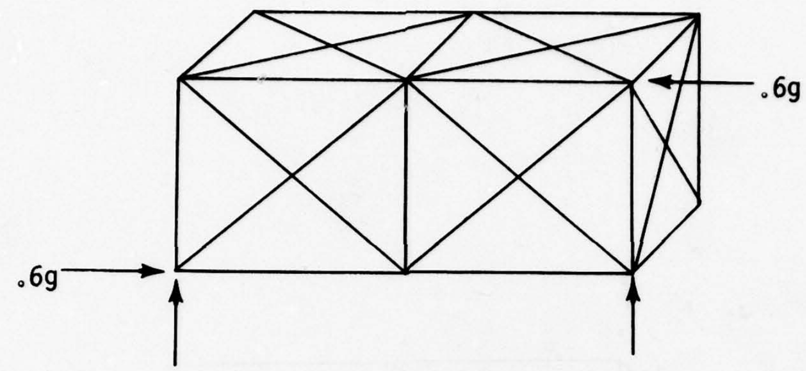
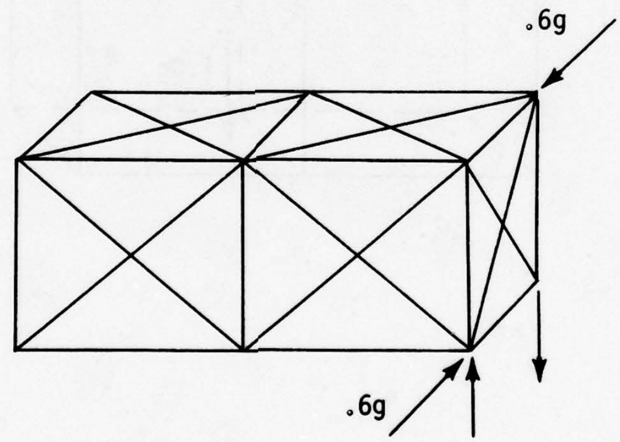


Figure A-5. HEGS-20 single-point suspension condition.



(a) Longitudinal racking.



(b) Lateral racking.

Figure A-6. HEGS-20 racking condition.

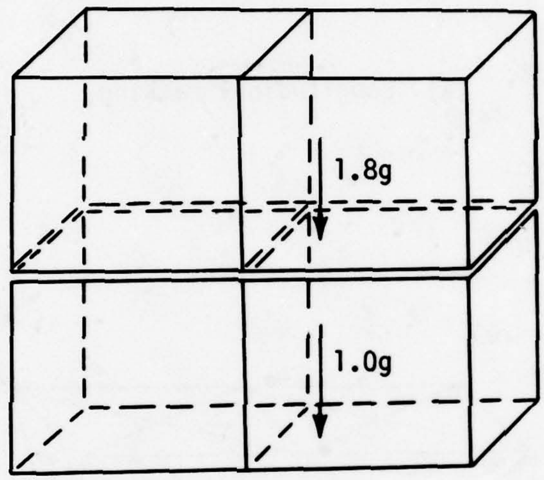


Figure A-7. HEGS-20 stacking condition.

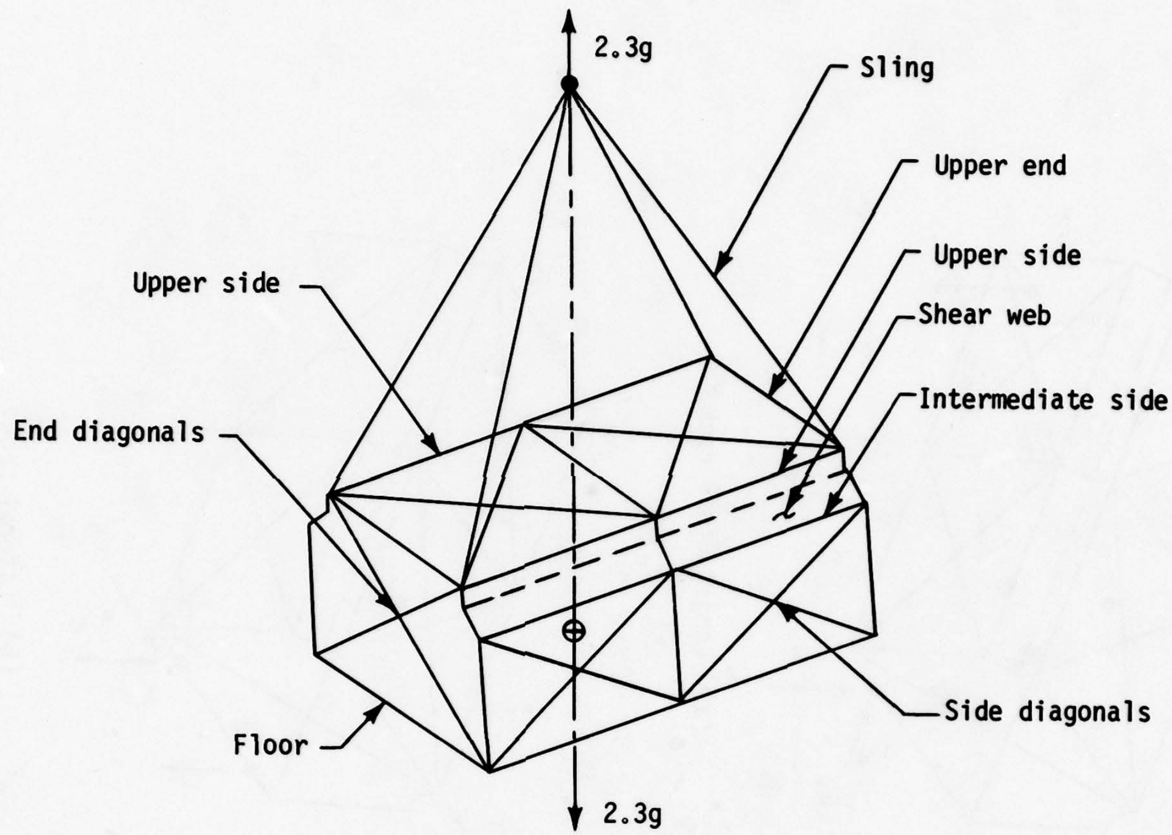
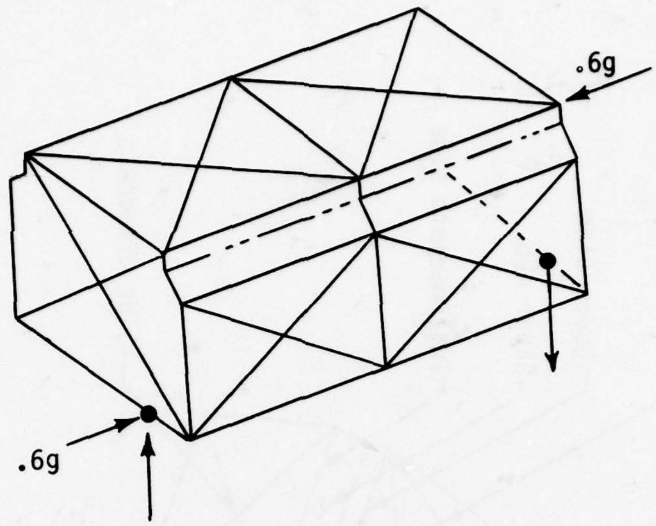
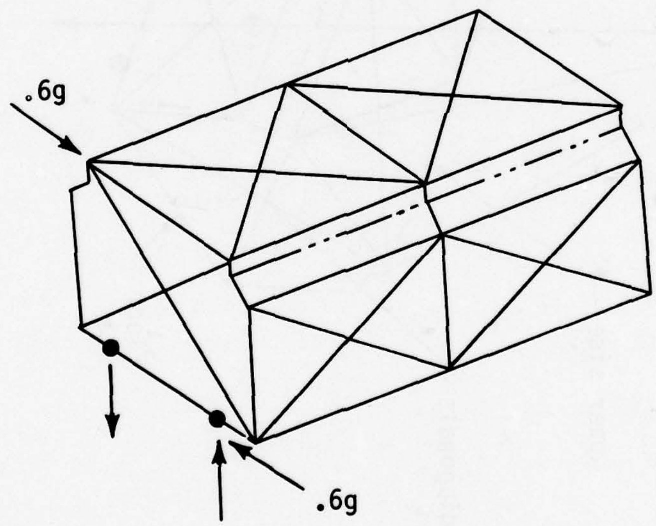


Figure A-8. HEGS-Palletized single-point suspension condition.



(a) Longitudinal rack.



(b) Lateral rack.

Figure A-9. HEGS-Palletized racking condition.

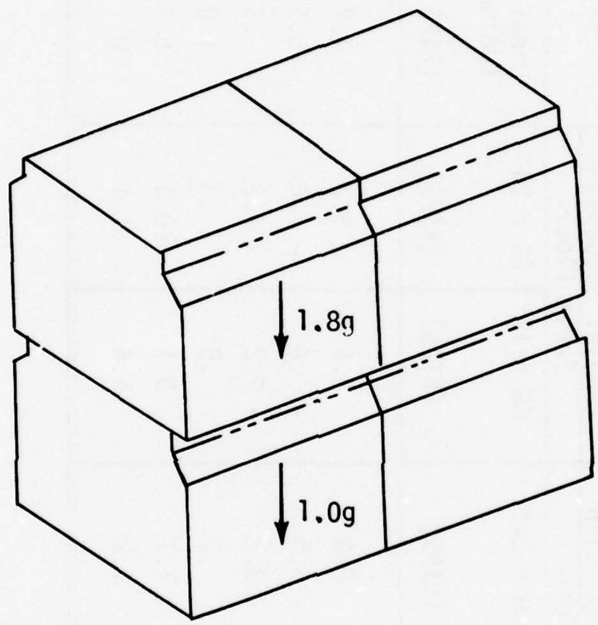


Figure A-10. HEGS-Palletized stacking condition.

TABLE A-3. MAXIMUM SUPERSTRUCTURE LIMIT LOADS FOR HEGS-10

MEMBER	1-Point Suspension Above Floor		2-Point Suspension Above Floor		.6-g Racking		2-High Stacking
	CG = 12" (KIPS)	CG = 24" (KIPS)	CG = 12" (KIPS)	CG = 24" (KIPS)	Longi-tudinal (KIPS)	Lateral (KIPS)	1.8-g 1.0-g (KIPS)
COLUMN	7.8	8.0	6.4	5.2	- 4.2	- 5.1	- 5.2
UPPER SIDE	- 3.8	- 3.8	- .6	- .6	- 5.6	- .8	- .8
UPPER END	- 3.2	- 3.2	- 7.2	- 7.2	- .6	- 5.4	- .6
UPPER DIAGONAL	.2	.2	.8	.8	1.0	1.0	1.0
SIDE DIAGONAL	1.0	1.1	9.1	10.3	6.3	0	0
END DIAGONAL	1.2	1.2	1.4	1.4	0	7.0	0

TABLE A-4. MAXIMUM SUPERSTRUCTURE LIMIT LOADS FOR HEGS-20

MEMBER	1-Point Suspension Above Floor		.6-g Racking		2-High Stacking
	CG = 12" (KIPS)	CG = 24" (KIPS)	Longitudinal (KIPS)	Lateral (KIPS)	1.8-g 1.0-g (KIPS)
CORNER COLUMN	9.0	9.3	- 6.2	- 16.0	- 16.2
CENTER COLUMN	0	0	- 6.2	0	0
UPPER SIDE	- 22.0	- 22.1	- 17.5	- 2.5	- 2.5
UPPER END	- 4.0	- 4.0	- 2.0	- 17.0	- 2.0
UPPER CENTER LATERAL	- .2	- .2	- 3.9	- 3.9	- 3.9
UPPER DIAGONAL	.2	.2	3.2	3.2	3.2
SIDE DIAGONAL	18.6	18.7	9.7	0	0
END DIAGONAL	1.5	1.6	0	21.9	0

TABLE A-5. MAXIMUM SUPERSTRUCTURE LIMIT LOADS FOR HEGS-PALLETIZED

MEMBER	1-Point Suspension Above Floor		.6-g Racking		2-High Stacking
	CG = 12" (KIPS)	CG = 24" (KIPS)	Longi-tudinal (KIPS)	Lateral (KIPS)	1.8-g 1.0-g (KIPS)
CORNER COLUMN	9.0	9.3	- 6.2	- 12.4	- 16.2
CENTER COLUMN	0	0	- 6.2	0	0
UPPER SIDE	- 22.0	- 22.1	- 7.5	0	- 2.5
UPPER END	- 4.0	- 4.0	- 2.0	- 17.0	- 2.0
UPPER CENTER LATERAL	- .2	- .2	- 3.9	- 3.9	- 3.9
INTERMEDIATE SIDE	- 6.8	- 7.1	- 7.5	0	0
UPPER DIAGONAL	.2	.2	3.2	3.2	3.2
SIDE DIAGONAL	18.6	18.7	8.8	0	0
END DIAGONAL	1.5	1.6	1.0	18.2	0

TABLE A-6. CRITICAL SUPERSTRUCTURE LIMIT LOADS			
		MAXIMUM LOAD (kips)	
MODULE	COMPONENT	TENSION	COMPRESSION
HEGS-10	Column	8.0	- 5.2
	Upper side	0	- 5.6
	Upper end	0	- 7.2
	Upper diagonal	1.0	0
	Side diagonal	10.3	0
	End diagonal	7.0	0
HEGS-20	Corner column	9.3	- 16.2
	Center column	0	- 6.2
	Upper side	0	- 22.1
	Upper end	0	- 17.0
	Upper center lateral	0	- 3.9
	Upper diagonal	3.2	0
	Side diagonal	18.7	0
	End diagonal	21.9	0
HEGS-Palletized	Corner column	9.3	- 16.2
	Center column	0	- 6.2
	Upper side	0	- 22.1
	Upper end	0	- 17.0
	Upper center lateral	0	- 3.9
	Intermediate side	0	- 7.5
	Upper diagonal	3.2	0
	Side diagonal	18.7	0
	End diagonal	18.2	0

FLOOR-BEAM GRID

The floor of the HEGS-10 is supported at its four corners. Figure A-11 shows the main structural beams of the floor and the supports. The beams are created by welding T-sections and angle-sections to the plate which forms the surface of the floor; thus, the floor surface itself becomes an integral part of the beams. There are:

1. Six longitudinal beams which support interior loads
2. Two lateral beams which support the ends of the longitudinal beams and transfer load to the reaction points at the corners of the floor
3. One lateral beam which interconnects the longitudinal beams at their midspan.

The structural integrity of the floor-beam grid was analyzed using NASTRAN. Figure A-12 shows the structural model with numbered nodes and elements. Element numbers are circled. The section properties and cross sections for the various elements are shown in Figure A-13.

The gondolas are designed for an ultimate load that equals 1.5 times the limit load. Since the aluminum alloy 5456, from which the floor is made, has an ultimate strength (after welding) greater than 1.5 times the yield strength, the margins of safety for limit loads (which are based upon yield strengths) are lower than the margins of safety for the corresponding ultimate load. The NASTRAN analysis herein shows the limit load case.

The NASTRAN analysis corresponds to an off-center load of 8,000 pounds at 1-g. Using a limit load factor of 3.2, the applied load for the analysis is 8.0 x 3.2 = 25.6 kips (limit). The centroid of the load lies at the geometrical 60% position of the floor in the longitudinal and lateral directions, as shown in Figure A-14. The loaded area corresponds to 300 psf at 1-g, 300 x 3.2 = 960 psf at limit, and 960 x 1.5 = 1440 psf at ultimate.

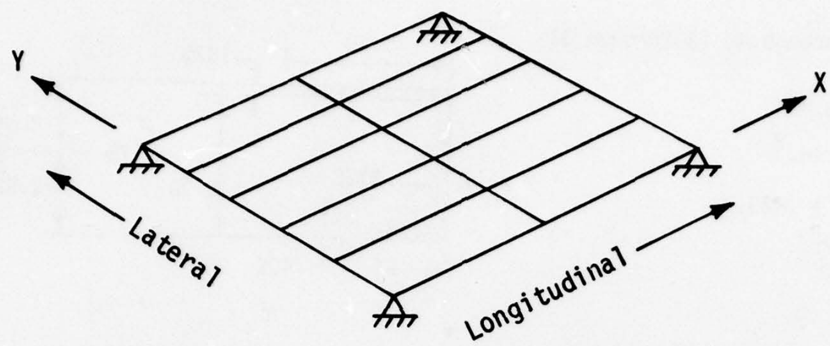


Figure A-11. Main floor-beam grid for HEGS-10.

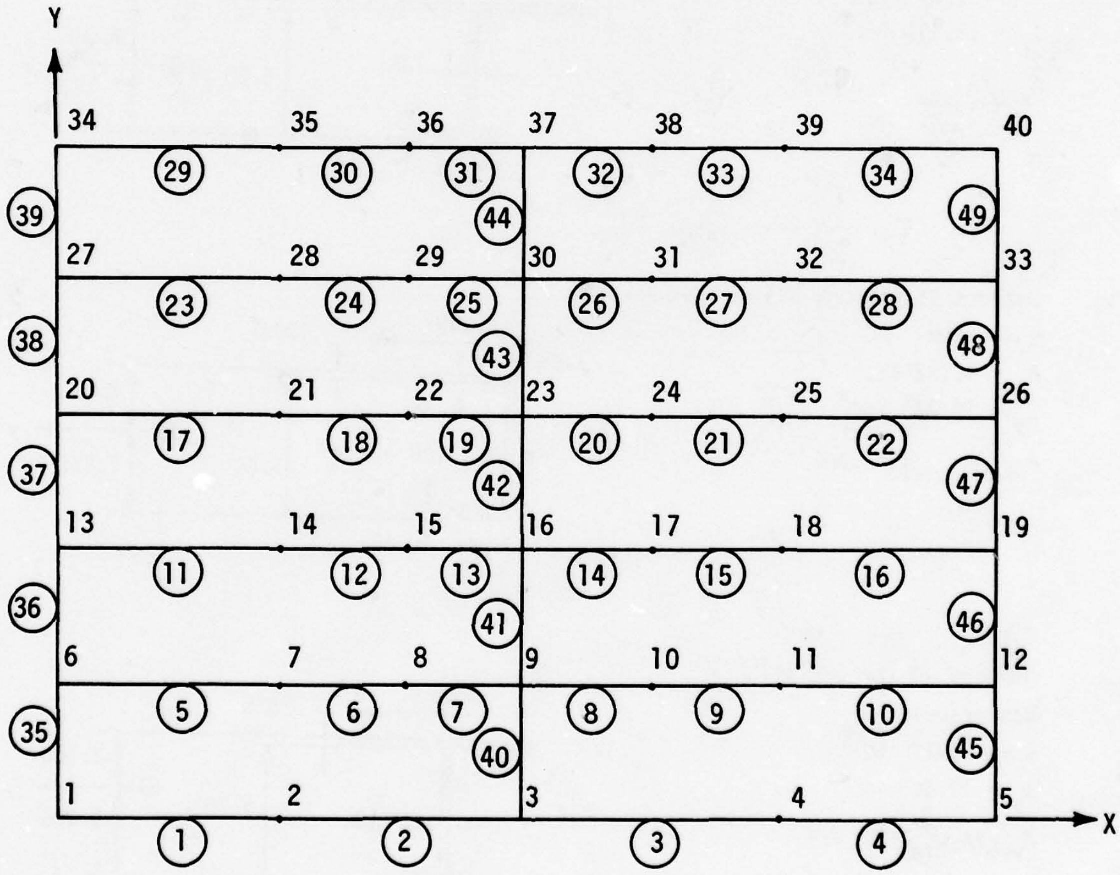


Figure A-12. NASTRAN model for floor-beam grid of HEGS-10.

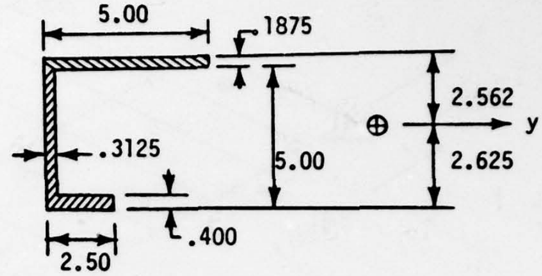
Members 1 through 4, 29 through 34

Edge-beams

$A = 3.375 \text{ in.}^2$

$I_y = 14.143 \text{ in.}^2$

$A_{web}/A_{total} = .480$



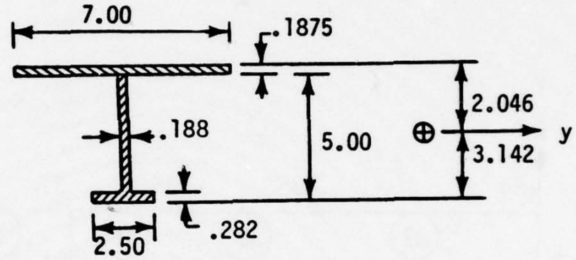
Members 5 through 28

T-beams

$A = 2.904 \text{ in.}^2$

$I_y = 13.331 \text{ in.}^4$

$A_{web}/A_{total} = .336$



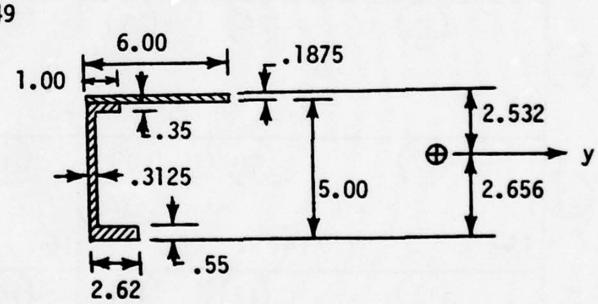
Members 35 through 39, 45 through 49

End-beams

$A = 4.197 \text{ in.}^2$

$I_y = 18.340 \text{ in.}^4$

$A_{web}/A_{total} = .386$



Members 40 through 44

Center-beam

$A = 2.717 \text{ in.}^2$

$I_y = 12.563 \text{ in.}^2$

$A_{web}/A_{total} = .359$

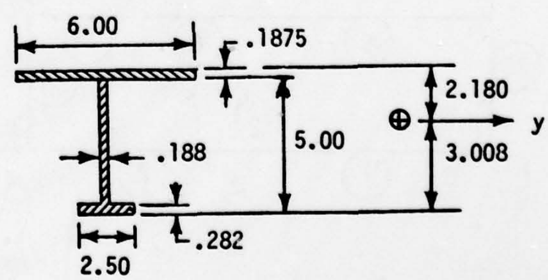


Figure A-13. Section properties and cross sections for elements of HEGS-10.

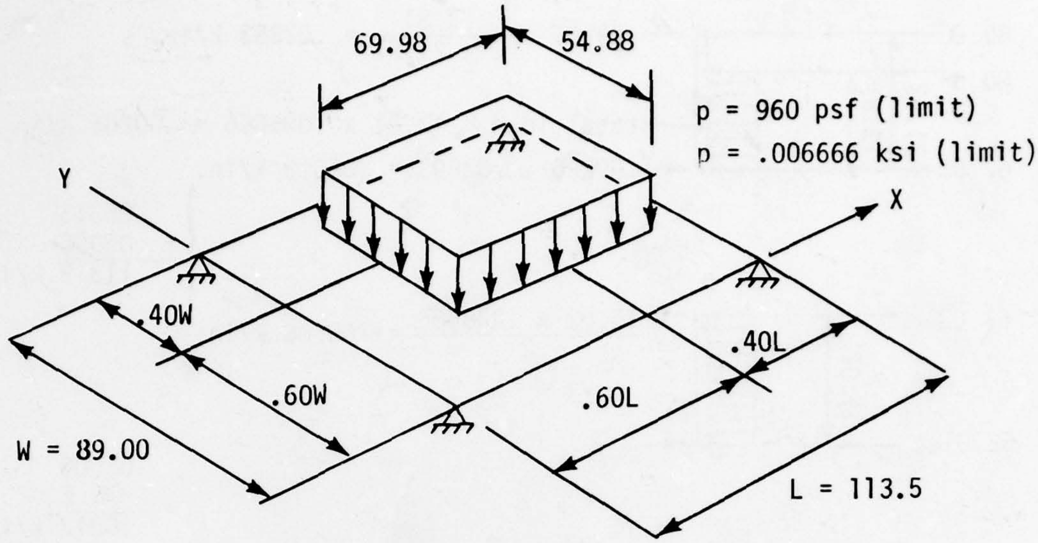


Figure A-14. Loading for HEGS-10, case 3.01.

The calculations to determine the loaded area are:

Intensity of load	= p	= 300 psf at 1-g
Footprint of load	= P/p	= 8.0/.3 = 26.67 sq. ft.
Total floor area	= WL	= 113.5 x 89/144 = 70.15 sq. ft.
Loaded area/total area	= R = P/pWL	= 26.67/70.15 = .380185
Loaded length	= $\sqrt{R}$ L	= $\sqrt{.380185}$ x 113.5 = 69.98 in.
Loaded width	= $\sqrt{R}$ W	= $\sqrt{.380185}$ x 89.00 = 54.88 in.

Loaded footprint between:

$x = .6L \pm \sqrt{R}\,L/2 = 68.1 \pm 69.98/2;$

33.11 to 103.09 in.

$y = .6W \pm \sqrt{R}\,W/2 = 53.4 \pm 54.88/2;$

25.96 to 80.84 in.

The corresponding loads acting upon the longitudinal beams of the NASTRAN model are calculated in Figure A-15.

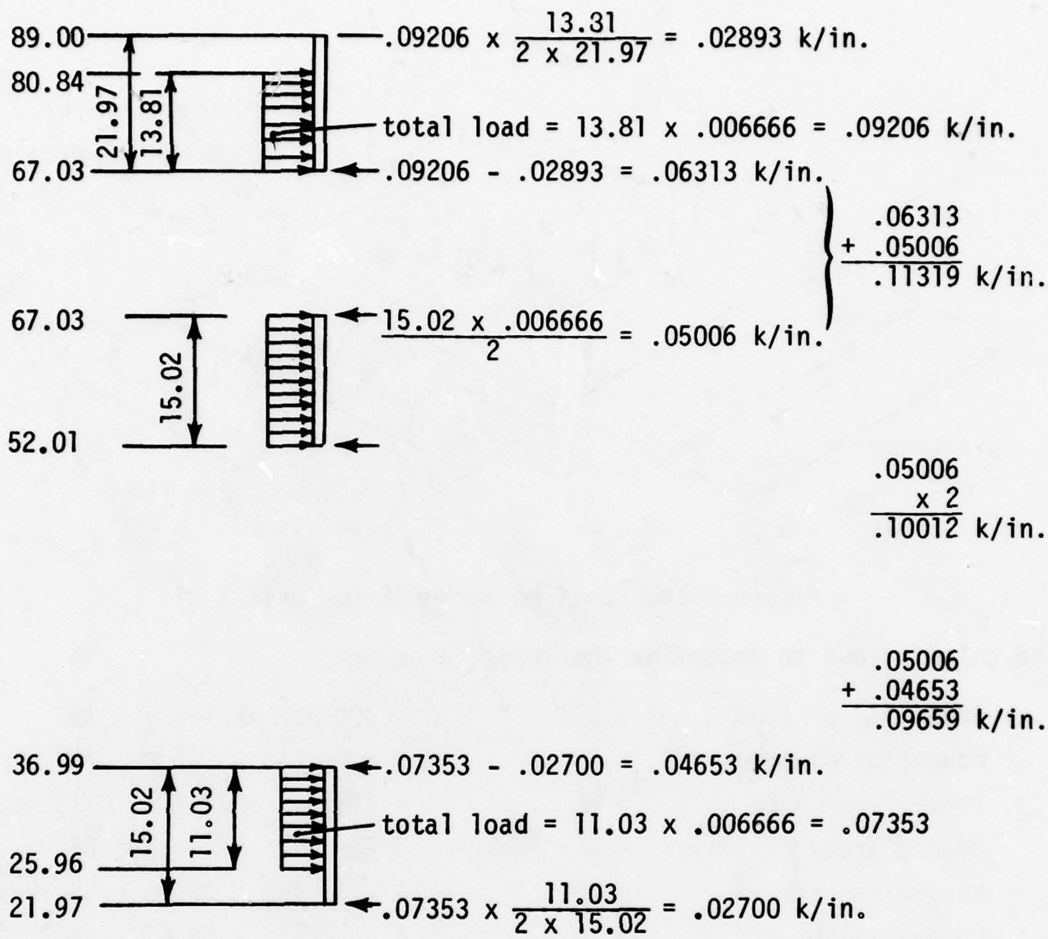


Figure A-15. Loadings on beams of HEGS-10, case 3.01.

Table A-7 presents the results from the NASTRAN analysis. The margins of safety are everywhere positive. The minimum margins of safety are:

+ .01 in the edge beams, member 32

+ .12 in the T-beams, member 26

+ .03 in the end beams, member 48

+ .11 in the center beam, member 42

TABLE A-7. HEGS-10 FLOOR ANALYSIS

```
N A S T R A N   E X E C U T I V E   C O N T R O L   D E C K   E C H O

ID KAMAN, GONDOLA
SOL 1
TIME 2
DIAG 8,13,16
CEND

                         C A S E   C O N T R O L   D E C K   E C H O
CARD
COUNT
  1      TITLE = HEGS-10 GONDOLA
  2      SUBCASE 1
  3          SUBTITLE = RUN 3.01, FLOOR GRID, LIMIT LOAD, 60-40 DIST., 960 PSF
  4          LOAD = 201
  5          DISP = ALL
  6          ELFO = ALL
  7          STRESS = ALL
  8          OLOAD = ALL
  9          SPCFORCES = ALL
 10      BEGIN BULK

        TOTAL COUNT=  141
```

TABLE A-7. HEGS-10 FLOOR ANALYSIS (continued)

HEGS-10 GONDOLA

SORTED BULK DATA ECHO

CARD COUNT	. 1 ..	2 ..	3 ..	4 ..	5 ..	6 ..	7 ..	8 ..	9 ..	10 .
1-	CHAR	1	1	1	2	6			2	BC11
2-	+C11	5								
3-	CBAR	2	1	2	3	7			2	
4-	CBAR	3	1	3	4	9			2	
5-	CBAR	4	1	4	5	11			2	BC41
6-	+C41		5							
7-	CBAR	5	2	6	7	13			2	BC51
8-	+C51	4								
9-	CBAR	6	2	7	8	14			2	
10-	CBAR	7	2	8	9	15			2	
11-	CBAR	8	2	9	10	16			2	
12-	CHAR	9	2	10	11	17			2	
13-	CBAR	10	2	11	12	18			2	BC101
14-	+C101		5							
15-	CBAR	11	2	13	14	20			2	BC111
16-	+C111	5								
17-	CBAR	12	2	14	15	21			2	
18-	CHAR	13	2	15	16	22			2	
19-	CHAR	14	2	16	17	23			2	
20-	CHAR	15	2	17	18	24			2	
21-	CBAR	16	2	18	19	25			2	BC161
22-	+C161		5							
23-	CBAR	17	2	20	21	27			2	BC171
24-	+C171	5								
25-	CBAR	18	2	21	22	28			2	
26-	CHAR	19	2	22	23	29			2	
27-	CBAR	20	2	23	24	30			2	
28-	CHAR	21	2	24	25	31			2	
29-	CBAR	22	2	25	26	32			2	BC221
30-	+C221		5							
31-	CBAR	23	2	27	28	34			2	BC231
32-	+C231	5								
33-	CBAR	24	2	28	29	35			2	
34-	CHAR	25	2	29	30	36			2	
35-	CHAR	26	2	30	31	37			2	
36-	CHAR	27	2	31	32	38			2	
37-	CHAR	28	2	32	33	39			2	BC281
38-	+C281		5							
39-	CHAR	29	1	34	35	200.	200.		1	BC291
40-	+C291	5								
41-	CHAR	30	1	35	36	200.	200.		1	
42-	CHAR	31	1	36	37	200.	200.		1	
43-	CHAR	32	1	37	38	200.	200.		1	
44-	CHAR	33	1	38	39	200.	200.		1	
45-	CHAR	34	1	39	40	200.	200.		1	BC341
46-	+C341		5							
47-	CBAR	35	3	1	6	-100.	200.		1	
48-	CBAR	36	3	6	13	-100.	200.		1	
49-	CBAR	37	3	13	20	-100.	200.		1	
50-	CBAR	38	3	20	27	-100.	200.		1	

TABLE A-7. HEGS-10 FLOOR ANALYSIS (continued)

HEGS-10 GONDOLA

SORTED BULK DATA ECHO

CARD COUNT	. 1 ..	2 ..	3 ..	4 ..	5 ..	6 ..	7 ..	8 ..	9 ..	10 .
51-	CBAR	39	3	27	34	-100.	200.		1	
52-	CBAR	40	4	3	9	1			2	
53-	CBAR	41	4	9	16	6			2	
54-	CBAR	42	4	16	23	13			2	
55-	CBAR	43	4	23	30	20			2	
56-	CBAR	44	4	30	37	27			2	
57-	CBAR	45	3	5	12	3			2	
58-	CBAR	46	3	12	19	9			2	
59-	CBAR	47	3	19	26	16			2	
60-	CBAR	48	3	26	33	23			2	
61-	CBAR	49	3	33	40	30			2	
62-	GRID	1		.0	.0			1263		
63-	GRID	2		28.37	.0			126		
64-	GRID	3		56.75	.0			126		
65-	GRID	4		85.57	.0			126		
66-	GRID	5		113.50	.0			1263		
67-	GRID	6		.0	21.97			126		
68-	GRID	7		28.37	21.97			126		
69-	GRID	8		42.56	21.97			126		
70-	GRID	9		56.75	21.97			126		
71-	GRID	10		71.16	21.97			126		
72-	GRID	11		85.57	21.97			126		
73-	GRID	12		113.50	21.97			126		
74-	GRID	13		.0	36.99			126		
75-	GRID	14		28.37	36.99			126		
76-	GRID	15		42.56	36.99			126		
77-	GRID	16		56.75	36.99			126		
78-	GRID	17		71.16	36.99			126		
79-	GRID	18		85.57	36.99			126		
80-	GRID	19		113.50	36.99			126		
81-	GRID	20		.0	52.01			126		
82-	GRID	21		28.37	52.01			126		
83-	GRID	22		42.56	52.01			126		
84-	GRID	23		56.75	52.01			126		
85-	GRID	24		71.16	52.01			126		
86-	GRID	25		85.57	52.01			126		
87-	GRID	26		113.50	52.01			126		
88-	GRID	27		.0	67.03			126		
89-	GRID	28		28.37	67.03			126		
90-	GRID	29		42.56	67.03			126		
91-	GRID	30		56.75	67.03			126		
92-	GRID	31		71.16	67.03			126		
93-	GRID	32		85.57	67.03			126		
94-	GRID	33		113.50	67.03			126		
95-	GRID	34		.0	89.00			1263		
96-	GRID	35		28.37	89.00			126		
97-	GRID	36		42.56	89.00			126		
98-	GRID	37		56.75	89.00			126		
99-	GRID	38		71.16	89.00			126		
100-	GRID	39		85.57	89.00			126		

TABLE A-7. HEGS-10 FLOOR ANALYSIS (continued)

HEGS-10 GONDOLA

SORTED BULK DATA ECHO

CARD COUNT	1	2	3	4	5	6	7	8	9	10
101-	GRID	40		113.50	89.00			1263		
102-	MAT1	1	10400.	4000.						MA11
103-	+A11	26.0	27.0	15.						
104-	PBAR	1	1	3.375	1.	14.143	.1			PB11
105-	+B11	.0	2.562	.0	-2.625					PB12
106-	+B12	.480	.480							
107-	PBAR	2	1	2.904	1.	13.331	.1			PB21
108-	+B21	.0	2.046	.0	-3.142					PB22
109-	+B22	.336	.336							
110-	PBAR	3	1	4.197	1.	18.340	.1			PB31
111-	+B31	.0	2.532	.0	-2.656					PB32
112-	+B32	.386	.386							
113-	PBAR	4	1	2.717	1.	12.563	.1			PB41
114-	+B41	.0	2.180	.0	-3.008					PB42
115-	+B42	.359	.359							
116-	PLOAD1	201	6	FZ	FR	.333	-.02700	1.00	-.02700	
117-	PLOAD1	201	7	FZ	FR	.000	-.02700	1.00	-.02700	
118-	PLOAD1	201	8	FZ	FR	.000	-.02700	1.00	-.02700	
119-	PLOAD1	201	9	FZ	FR	.000	-.02700	1.00	-.02700	
120-	PLOAD1	201	10	FZ	FR	.000	-.02700	.618	-.02700	
121-	PLOAD1	201	12	FZ	FR	.333	-.09659	1.00	-.09659	
122-	PLOAD1	201	13	FZ	FR	.000	-.09659	1.00	-.09659	
123-	PLOAD1	201	14	FZ	FR	.000	-.09659	1.00	-.09659	
124-	PLOAD1	201	15	FZ	FR	.000	-.09659	1.00	-.09659	
125-	PLOAD1	201	16	FZ	FR	.000	-.09659	.618	-.09659	
126-	PLOAD1	201	18	FZ	FR	.333	-.10012	1.00	-.10012	
127-	PLOAD1	201	19	FZ	FR	.000	-.10012	1.00	-.10012	
128-	PLOAD1	201	20	FZ	FR	.000	-.10012	1.00	-.10012	
129-	PLOAD1	201	21	FZ	FR	.000	-.10012	1.00	-.10012	
130-	PLOAD1	201	22	FZ	FR	.000	-.10012	.618	-.10012	
131-	PLOAD1	201	24	FZ	FR	.333	-.11319	1.00	-.11319	
132-	PLOAD1	201	25	FZ	FR	.000	-.11319	1.00	-.11319	
133-	PLOAD1	201	26	FZ	FR	.000	-.11319	1.00	-.11319	
134-	PLOAD1	201	27	FZ	FR	.000	-.11319	1.00	-.11319	
135-	PLOAD1	201	28	FZ	FR	.000	-.11319	.618	-.11319	
136-	PLOAD1	201	30	FZ	FR	.333	-.02893	1.00	-.02893	
137-	PLOAD1	201	31	FZ	FR	.000	-.02893	1.00	-.02893	
138-	PLOAD1	201	32	FZ	FR	.000	-.02893	1.00	-.02893	
139-	PLOAD1	201	33	FZ	FR	.000	-.02893	1.00	-.02893	
140-	PLOAD1	201	34	FZ	FR	.000	-.02893	.618	-.02893	
	ENDDATA									

TOTAL COUNT= 140

TABLE A-7. HEGS-10 FLOOR ANALYSIS (continued)

HEGS-10 GONDOLA
RUN 3.01, FLOOR GRID, LIMIT LOAD, 60-40 DIST., 960 PSF

SUBCASE 1

D I S P L A C E M E N T   V E C T O R

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
1	G	0.0	0.0	0.0	-1.452058E-02	1.620372E-02	0.0
2	G	0.0	0.0	-2.902249E-01	-1.944745E-02	8.244459E-03	0.0
3	G	0.0	0.0	-4.246448E-01	-2.537623E-02	2.660298E-06	0.0
4	G	0.0	0.0	-2.865657E-01	-2.501578E-02	-8.329577E-03	0.0
5	G	0.0	0.0	0.0	-2.466646E-02	0.0	0.0
6	G	0.0	0.0	-3.007580E-01	-1.060075E-02	1.620372E-02	0.0
7	G	0.0	0.0	-7.354280E-01	-2.168082E-02	1.260363E-02	0.0
8	G	0.0	0.0	-8.887262E-01	-2.168082E-02	8.129128E-03	0.0
9	G	0.0	0.0	-9.664551E-01	-2.168082E-02	2.227884E-03	0.0
10	G	0.0	0.0	-9.510992E-01	-2.079839E-02	-3.930328E-03	0.0
11	G	0.0	0.0	-8.530392E-01	-1.991597E-02	-8.954332E-03	0.0
12	G	0.0	0.0	-5.119152E-01	-1.820562E-02	0.0	0.0
13	G	0.0	0.0	-4.185855E-01	-4.152657E-03	1.620372E-02	0.0
14	G	0.0	0.0	-9.607469E-01	-9.100736E-03	1.575210E-02	0.0
15	G	0.0	0.0	-1.152129E+00	-1.157565E-02	1.028766E-02	0.0
16	G	0.0	0.0	-1.252697E+00	-1.405056E-02	3.937418E-03	0.0
17	G	0.0	0.0	-1.263407E+00	-1.233751E-02	-3.130954E-03	0.0
18	G	0.0	0.0	-1.162501E+00	-1.062446E-02	-1.049347E-02	0.0
19	G	0.0	0.0	-7.167622E-01	-7.304161E-03	0.0	0.0
20	G	0.0	0.0	-4.240679E-01	3.583540E-03	1.620372E-02	0.0
21	G	0.0	0.0	-1.053387E+00	1.360454E-04	1.821690E-02	0.0
22	G	0.0	0.0	-1.274058E+00	-1.588309E-03	1.174998E-02	0.0
23	G	0.0	0.0	-1.386926E+00	-3.312664E-03	4.043691E-03	0.0
24	G	0.0	0.0	-1.388045E+00	-9.378609E-04	-4.424360E-03	0.0
25	G	0.0	0.0	-1.259413E+00	1.436942E-03	-1.286534E-02	0.0
26	G	0.0	0.0	-7.286521E-01	6.039875E-03	0.0	0.0
27	G	0.0	0.0	-3.116619E-01	1.062957E-02	1.620372E-02	0.0
28	G	0.0	0.0	-1.001579E+00	8.715271E-03	1.977599E-02	0.0
29	G	0.0	0.0	-1.238884E+00	7.757783E-03	1.236678E-02	0.0
30	G	0.0	0.0	-1.352644E+00	6.800294E-03	3.517157E-03	0.0
31	G	0.0	0.0	-1.337582E+00	9.707364E-03	-6.193300E-03	0.0
32	G	0.0	0.0	-1.174144E+00	1.261443E-02	-1.583332E-02	0.0
33	G	0.0	0.0	-5.365250E-01	1.824903E-02	0.0	0.0
34	G	0.0	0.0	0.0	1.513843E-02	1.620372E-02	0.0
35	G	0.0	0.0	-7.430627E-01	1.424247E-02	2.109544E-02	0.0
36	G	0.0	0.0	-9.895483E-01	1.379434E-02	1.230915E-02	0.0
37	G	0.0	0.0	-1.087526E+00	1.334620E-02	3.745300E-04	0.0
38	G	0.0	0.0	-9.972071E-01	1.657735E-02	-1.190324E-02	0.0
39	G	0.0	0.0	-7.492805E-01	1.980850E-02	-2.127349E-02	0.0
40	G	0.0	0.0	0.0	2.607123E-02	0.0	0.0

TABLE A-7. HEGS-10 FLOOR ANALYSIS (continued)

HEGS-10 GONDOLA
RUN 3.01, FLOOR GRID, LIMIT LOAD, 60-40 DIST., 960 PSF

SUBCASE 1

L O A D   V E C T O R

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
7	G	0.0	0.0	-8.219321E-02	0.0	3.142831E-01	0.0
8	G	0.0	0.0	-3.649195E-01	0.0	9.574472E-02	0.0
9	G	0.0	0.0	-3.861000E-01	0.0	1.415700E-02	0.0
10	G	0.0	0.0	-3.890700E-01	0.0	-3.552714E-15	0.0
11	G	0.0	0.0	-5.770646E-01	0.0	1.222445E+00	0.0
12	G	0.0	0.0	-8.351036E-02	0.0	0.0	0.0
14	G	0.0	0.0	-2.940386E-01	0.0	1.124319E+00	0.0
15	G	0.0	0.0	-1.305466E+00	0.0	3.425179E-01	0.0
16	G	0.0	0.0	-1.381237E+00	0.0	5.064536E-02	0.0
17	G	0.0	0.0	-1.391862E+00	0.0	-7.105427E-15	0.0
18	G	0.0	0.0	-2.064395E+00	0.0	4.373184E+00	0.0
19	G	0.0	0.0	-2.987506E-01	0.0	0.0	0.0
21	G	0.0	0.0	-3.047846E-01	0.0	1.165408E+00	0.0
22	G	0.0	0.0	-1.353176E+00	0.0	3.550356E-01	0.0
23	G	0.0	0.0	-1.431716E+00	0.0	5.249625E-02	0.0
24	G	0.0	0.0	-1.442729E+00	0.0	-1.421085E-14	0.0
25	G	0.0	0.0	-2.139841E+00	0.0	4.533007E+00	0.0
26	G	0.0	0.0	-3.096688E-01	0.0	0.0	0.0
28	G	0.0	0.0	-3.445722E-01	0.0	1.317545E+00	0.0
29	G	0.0	0.0	-1.529824E+00	0.0	4.013831E-01	0.0
30	G	0.0	0.0	-1.618617E+00	0.0	5.934929E-02	0.0
31	G	0.0	0.0	-1.631068E+00	0.0	-1.421085E-14	0.0
32	G	0.0	0.0	-2.419183E+00	0.0	5.124761E+00	0.0
33	G	0.0	0.0	-3.500940E-01	0.0	0.0	0.0
35	G	0.0	0.0	-8.701325E-02	0.0	3.292615E-01	0.0
36	G	0.0	0.0	-3.920597E-01	0.0	9.510165E-02	0.0
37	G	0.0	0.0	-4.136990E-01	0.0	1.516896E-02	0.0
38	G	0.0	0.0	-4.168813E-01	0.0	-3.552714E-15	0.0
39	G	0.0	0.0	-6.212541E-01	0.0	1.391942E+00	0.0
40	G	0.0	0.0	-8.653976E-02	0.0	0.0	0.0

F O R C E S   O F   S I N G L E - P O I N T   C O N S T R A I N T

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
1	G	0.0	0.0	4.094599E+00	0.0	0.0	0.0
5	G	0.0	0.0	6.110035E+00	0.0	0.0	0.0
34	G	0.0	0.0	6.140724E+00	0.0	0.0	0.0
40	G	0.0	0.0	9.165969E+00	0.0	0.0	0.0

TABLE A-7. HEGS-10 FLOOR ANALYSIS (continued)

HEGS-10 GONDOLA
RUN 3.01, FLOOR GRID, LIMIT LOAD, 60-40 DIST., 960 PSF

SUBCASE 1

F O R C E S   I N   B A R   E L E M E N T S   (C B A R)

ELEMENT ID.	BEND-MOMENT END-A PLANE 1	BEND-MOMENT END-A PLANE 2	BEND-MOMENT END-B PLANE 1	BEND-MOMENT END-B PLANE 2	- SHEAR - PLANE 1	- SHEAR - PLANE 2	AXIAL FORCE	TORQUE
1	0.0	0.0	0.0	2.847359E+01	0.0	-1.003651E+00	0.0	-7.651558E-02
2	0.0	2.847359E+01	0.0	5.695722E+01	0.0	-1.003651E+00	0.0	-7.651558E-02
3	0.0	5.699773E+01	0.0	2.805192E+01	0.0	1.004365E+00	0.0	5.002739E-03
4	0.0	2.805192E+01	0.0	-6.821210E-13	0.0	1.004365E+00	0.0	5.002739E-03
5	0.0	0.0	0.0	3.518683E+01	0.0	-1.240283E+00	0.0	0.0
6	0.0	3.550111E+01	0.0	5.193441E+01	0.0	-1.158090E+00	0.0	0.0
7	0.0	5.203015E+01	0.0	6.328524E+01	0.0	-7.931703E-01	0.0	0.0
8	0.0	6.330441E+01	0.0	5.519514E+01	0.0	5.627527E-01	0.0	2.449474E-02
9	0.0	5.519514E+01	0.0	4.147938E+01	0.0	9.518227E-01	0.0	2.449474E-02
10	0.0	4.270182E+01	0.0	-6.821210E-13	0.0	1.528867E+00	0.0	2.449474E-02
11	0.0	1.522805E-12	0.0	4.347837E+01	0.0	-1.532547E+00	0.0	-6.976495E-02
12	0.0	4.460269E+01	0.0	6.217713E+01	0.0	-1.238509E+00	0.0	-6.976495E-02
13	0.0	6.251964E+01	0.0	6.156953E+01	0.0	6.695696E-02	0.0	-6.976495E-02
14	0.0	6.157747E+01	0.0	7.443585E+01	0.0	-8.923231E-01	0.0	4.755170E-02
15	0.0	7.443565E+01	0.0	6.723750E+01	0.0	4.995388E-01	0.0	4.755170E-02
16	0.0	7.161068E+01	0.0	-5.002221E-12	0.0	2.563934E+00	0.0	4.755170E-02
17	0.0	1.542750E-12	0.0	5.134165E+01	0.0	-1.809716E+00	0.0	-4.860761E-02
18	0.0	5.250705E+01	0.0	7.386203E+01	0.0	-1.504932E+00	0.0	-4.860761E-02
19	0.0	7.421707E+01	0.0	7.637049E+01	0.0	-1.517560E-01	0.0	-4.860761E-02
20	0.0	7.640613E+01	0.0	8.654056E+01	0.0	-7.032913E-01	0.0	6.592098E-02
21	0.0	8.654056E+01	0.0	7.588526E+01	0.0	7.394379E-01	0.0	6.592098E-02
22	0.0	8.041826E+01	0.0	-2.728484E-12	0.0	2.879279E+00	0.0	6.592098E-02
23	0.0	1.133819E-12	0.0	5.881056E+01	0.0	-2.072984E+00	0.0	-2.699052E-02
24	0.0	6.012810E+01	0.0	8.465427E+01	0.0	-1.728412E+00	0.0	-2.699052E-02
25	0.0	8.505565E+01	0.0	8.787362E+01	0.0	-1.985883E-01	0.0	-2.699052E-02
26	0.0	8.788977E+01	0.0	9.896393E+01	0.0	-7.685051E-01	0.0	8.069592E-02
27	0.0	9.896393E+01	0.0	8.653440E+01	0.0	8.625628E-01	0.0	8.069592E-02
28	0.0	9.165916E+01	0.0	-1.818989E-12	0.0	3.281746E+00	0.0	8.069592E-02
29	0.0	0.0	0.0	7.308512E+01	0.0	-2.576141E+00	0.0	-1.263242E-02
30	0.0	7.341438E+01	0.0	1.087351E+02	0.0	-2.489128E+00	0.0	-1.263242E-02
31	0.0	1.088302E+02	0.0	1.365876E+02	0.0	-2.097068E+00	0.0	-1.263242E-02
32	0.0	1.386600E+02	0.0	1.119857E+02	0.0	1.851093E+00	0.0	8.969182E-02
33	0.0	1.119857E+02	0.0	7.930422E+01	0.0	2.267475E+00	0.0	8.969182E-02
34	0.0	8.069616E+01	0.0	-1.364242E-12	0.0	2.889229E+00	0.0	8.969182E-02
35	0.0	7.651558E-02	0.0	6.798463E+01	0.0	-3.090947E+00	0.0	0.0
36	0.0	6.798463E+01	0.0	9.578160E+01	0.0	-1.850664E+00	0.0	-6.750155E-14
37	0.0	9.585137E+01	0.0	1.006295E+02	0.0	-3.181169E-01	0.0	-5.329071E-14
38	0.0	1.006781E+02	0.0	7.827427E+01	0.0	1.491599E+00	0.0	-3.197442E-14
39	0.0	7.830126E+01	0.0	-1.263242E-02	0.0	3.564583E+00	0.0	-8.881784E-15
40	0.0	-8.151832E-02	0.0	4.403461E+01	0.0	-2.008017E+00	0.0	4.051385E-02
41	0.0	4.401011E+01	0.0	8.873726E+01	0.0	-2.977840E+00	0.0	4.552687E-02
42	0.0	8.861995E+01	0.0	9.619253E+01	0.0	-6.373226E-01	0.0	2.830167E-03
43	0.0	9.807800E+01	0.0	7.786215E+01	0.0	1.345929E+00	0.0	-1.402221E-02
44	0.0	7.775447E+01	0.0	1.023242E-01	0.0	3.534463E+00	0.0	-5.721669E-02
45	0.0	5.002739E-03	0.0	1.121766E+02	0.0	-5.105670E+00	0.0	0.0
46	0.0	1.122011E+02	0.0	1.646700E+02	0.0	-3.493272E+00	0.0	0.0
47	0.0	1.647176E+02	0.0	1.741890E+02	0.0	-6.305872E-01	0.0	0.0
48	0.0	1.742549E+02	0.0	1.358283E+02	0.0	2.558361E+00	0.0	0.0
49	0.0	1.359090E+02	0.0	-8.969182E-02	0.0	6.190201E+00	0.0	0.0

TABLE A-7. HEGS-10 FLOOR ANALYSIS (continued)

HEGS-10 GONDOLA
RUN 3.01. FLOOR GRID. LIMIT LOAD. 60-40 DIST.. 960 PSF

SUBCASE 1

STRESSES IN BAR ELEMENTS (CBAR)

ELEMENT ID.	SA1 SB1	SA2 SB2	SA3 SB3	SA4 SB4	AXIAL STRESS	SA-MAX SB-MAX	SA-MIN SB-MIN	M.S.-T M.S.-C
1	0.0 -5.157982E+00	0.0 5.284817E+00	0.0 0.0	0.0 0.0	0.0	0.0 5.284817E+00	0.0 -5.157982E+00	3.9E+00 4.2E+00
2	-5.157982E+00 -1.031778E+01	5.284817E+00 1.057150E+01	0.0 0.0	0.0 0.0	0.0	5.284817E+00 1.057150E+01	-5.157982E+00 -1.031778E+01	1.5E+00 1.6E+00
3	-1.032512E+01 -5.081597E+00	1.057902E+01 5.206554E+00	0.0 0.0	0.0 0.0	0.0	1.057902E+01 5.206554E+00	-1.032512E+01 -5.081597E+00	1.5E+00 1.6E+00
4	-5.081597E+00 1.235660E-13	5.206554E+00 -1.266045E-13	0.0 0.0	0.0 0.0	0.0	5.206554E+00 1.235660E-13	-5.081597E+00 -1.266045E-13	4.0E+00 4.3E+00
5	0.0 -5.400364E+00	0.0 8.293228E+00	0.0 0.0	0.0 0.0	0.0	0.0 8.293228E+00	0.0 -5.400364E+00	2.1E+00 4.0E+00
6	-5.448599E+00 -7.970730E+00	8.367301E+00 1.224048E+01	0.0 0.0	0.0 0.0	0.0	8.367301E+00 1.224048E+01	-5.448599E+00 -7.970730E+00	1.1E+00 2.4E+00
7	-7.985424E+00 -9.712819E+00	1.226305E+01 1.491578E+01	0.0 0.0	0.0 0.0	0.0	1.226305E+01 1.491578E+01	-7.985424E+00 -9.712819E+00	7.4E-01 1.8E+00
8	-9.715762E+00 -8.471177E+00	1.492029E+01 1.300901E+01	0.0 0.0	0.0 0.0	0.0	1.492029E+01 1.300901E+01	-9.715762E+00 -8.471177E+00	7.4E-01 1.8E+00
9	-8.471177E+00 -6.366124E+00	1.300901E+01 9.776326E+00	0.0 0.0	0.0 0.0	0.0	1.300901E+01 9.776326E+00	-8.471177E+00 -6.366124E+00	1.0E+00 2.2E+00
10	-6.553741E+00 1.046898E-13	1.006445E+01 -1.607700E-13	0.0 0.0	0.0 0.0	0.0	1.006445E+01 1.046898E-13	-6.553741E+00 -1.607700E-13	1.6E+00 3.1E+00
11	-2.337154E-13 -6.672923E+00	3.589119E-13 1.024747E+01	0.0 0.0	0.0 0.0	0.0	3.589119E-13 1.024747E+01	-2.337154E-13 -6.672923E+00	1.5E+00 3.0E+00
12	-6.845480E+00 -9.542750E+00	1.051246E+01 1.465460E+01	0.0 0.0	0.0 0.0	0.0	1.051246E+01 1.465460E+01	-6.845480E+00 -9.542750E+00	7.7E-01 1.8E+00
13	-9.595319E+00 -9.449497E+00	1.473533E+01 1.451140E+01	0.0 0.0	0.0 0.0	0.0	1.473533E+01 1.451140E+01	-9.595319E+00 -9.449497E+00	7.6E-01 1.8E+00
14	-9.450717E+00 -1.142418E+01	1.451327E+01 1.754388E+01	0.0 0.0	0.0 0.0	0.0	1.451327E+01 1.754388E+01	-9.450717E+00 -1.142418E+01	4.8E-01 1.4E+00
15	-1.142418E+01 -1.031940E+01	1.754388E+01 1.584729E+01	0.0 0.0	0.0 0.0	0.0	1.754388E+01 1.584729E+01	-1.142418E+01 -1.031940E+01	4.8E-01 1.4E+00
16	-1.099058E+01 7.677251E-13	1.687801E+01 -1.178980E-12	0.0 0.0	0.0 0.0	0.0	1.687801E+01 7.677251E-13	-1.099058E+01 -1.178980E-12	5.4E-01 1.5E+00

TABLE A-7. HEGS-10 FLOOR ANALYSIS (continued)

HEGS-10 GONDOLA
RUN 3.01, FLOOR GRID, LIMIT LOAD, 60-40 DIST., 960 PSF

SUBCASE 1

STRESSES IN BAR ELEMENTS (CBAR)

ELEMENT ID.	SA1 SB1	SA2 SB2	SA3 SB3	SA4 SB4	AXIAL STRESS	SA-MAX SB-MAX	SA-MIN SB-MIN	M.S.-T M.S.-C
17	-2.367764E-13	3.636127E-13	0.0	0.0	0.0	3.636127E-13	-2.367764E-13	1.1E+00
	-7.879755E+00	1.210078E+01	0.0	0.0		1.210078E+01	-7.879755E+00	2.4E+00
18	-8.058618E+00	1.237545E+01	0.0	0.0	0.0	1.237545E+01	-8.058618E+00	4.9E-01
	-1.133611E+01	1.740863E+01	0.0	0.0		1.740863E+01	-1.133611E+01	1.4E+00
19	-1.139060E+01	1.749231E+01	0.0	0.0	0.0	1.749231E+01	-1.139060E+01	4.4E-01
	-1.172110E+01	1.799986E+01	0.0	0.0		1.799986E+01	-1.172110E+01	1.3E+00
20	-1.172657E+01	1.800826E+01	0.0	0.0	0.0	1.800826E+01	-1.172657E+01	2.7E-01
	-1.328197E+01	2.039685E+01	0.0	0.0		2.039685E+01	-1.328197E+01	1.0E+00
21	-1.328197E+01	2.039685E+01	0.0	0.0	0.0	2.039685E+01	-1.328197E+01	2.7E-01
	-1.164663E+01	1.788549E+01	0.0	0.0		1.788549E+01	-1.164663E+01	1.0E+00
22	-1.234234E+01	1.895388E+01	0.0	0.0	0.0	1.895388E+01	-1.234234E+01	3.7E-01
	4.187592E-13	-6.430798E-13	0.0	0.0		4.187592E-13	-6.430798E-13	1.2E+00
23	-1.740150E-13	2.672313E-13	0.0	0.0	0.0	2.672313E-13	-1.740150E-13	8.8E-01
	-9.026060E+00	1.386113E+01	0.0	0.0		1.386113E+01	-9.026060E+00	2.0E+00
24	-9.228272E+00	1.417167E+01	0.0	0.0	0.0	1.417167E+01	-9.228272E+00	3.0E-01
	-1.299247E+01	1.995227E+01	0.0	0.0		1.995227E+01	-1.299247E+01	1.1E+00
25	-1.305407E+01	2.004687E+01	0.0	0.0	0.0	2.004687E+01	-1.305407E+01	2.6E-01
	-1.348657E+01	2.071104E+01	0.0	0.0		2.071104E+01	-1.348657E+01	1.0E+00
26	-1.348905E+01	2.071485E+01	0.0	0.0	0.0	2.071485E+01	-1.348905E+01	1.1E-01
	-1.518867E+01	2.332493E+01	0.0	0.0		2.332493E+01	-1.518867E+01	7.8E-01
27	-1.518867E+01	2.332493E+01	0.0	0.0	0.0	2.332493E+01	-1.518867E+01	1.1E-01
	-1.328103E+01	2.039540E+01	0.0	0.0		2.039540E+01	-1.328103E+01	7.8E-01
28	-1.406756E+01	2.160326E+01	0.0	0.0	0.0	2.160326E+01	-1.406756E+01	2.0E-01
	2.791728E-13	-4.287199E-13	0.0	0.0		2.791728E-13	-4.287199E-13	9.2E-01
29	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.2E-01
	-1.323935E+01	1.356490E+01	0.0	0.0		1.356490E+01	-1.323935E+01	1.0E+00
30	-1.329899E+01	1.362602E+01	0.0	0.0	0.0	1.362602E+01	-1.329899E+01	2.9E-01
	-1.969733E+01	2.018169E+01	0.0	0.0		2.018169E+01	-1.969733E+01	3.7E-01
31	-1.971456E+01	2.019934E+01	0.0	0.0	0.0	2.019934E+01	-1.971456E+01	1.1E-02
	-2.510510E+01	2.572244E+01	0.0	0.0		2.572244E+01	-2.510510E+01	7.5E-02
32	-2.511821E+01	2.573588E+01	0.0	0.0	0.0	2.573588E+01	-2.511821E+01	1.0E-02
	-2.028618E+01	2.078502E+01	0.0	0.0		2.078502E+01	-2.028618E+01	7.5E-02

TABLE A-7. HEGS-10 FLOOR ANALYSIS (continued)

HEGS-10 GONDOLA
RUN 3.01, FLOOR GRID, LIMIT LOAD, 60-40 DIST., 960 PSF

SUBCASE 1

S T R E S S E S   I N   B A R   E L E M E N T S   (C B A R)

ELEMENT ID.	SA1 / SB1	SA2 / SB2	SA3 / SB3	SA4 / SB4	AXIAL STRESS	SA-MAX / SB-MAX	SA-MIN / SB-MIN	M.S.-T / M.S.-C
33	-2.028618E+01	2.078502E+01	0.0	0.0	0.0	2.078502E+01	-2.028618E+01	2.5E-01
	-1.436593E+01	1.471920E+01	0.0	0.0		1.471920E+01	-1.436593E+01	3.3E-01
34	-1.461808E+01	1.497755E+01	0.0	0.0	0.0	1.497755E+01	-1.461808E+01	7.4E-01
	2.471320E-13	-2.532090E-13	0.0	0.0		2.471320E-13	-2.532090E-13	8.5E-01
35	-1.056366E-02	1.108099E-02	0.0	0.0	0.0	1.108099E-02	-1.056366E-02	1.6E+00
	-9.385882E+00	9.845538E+00	0.0	0.0		9.845538E+00	-9.385882E+00	1.9E+00
36	-9.385882E+00	9.845538E+00	0.0	0.0	0.0	9.845538E+00	-9.385882E+00	8.7E-01
	-1.322350E+01	1.387110E+01	0.0	0.0		1.387110E+01	-1.322350E+01	1.0E+00
37	-1.323313E+01	1.388120E+01	0.0	0.0	0.0	1.388120E+01	-1.323313E+01	7.8E-01
	-1.389279E+01	1.457317E+01	0.0	0.0		1.457317E+01	-1.389279E+01	9.4E-01
38	-1.389951E+01	1.458021E+01	0.0	0.0	0.0	1.458021E+01	-1.389951E+01	7.8E-01
	-1.080646E+01	1.133569E+01	0.0	0.0		1.133569E+01	-1.080646E+01	9.4E-01
39	-1.081019E+01	1.133959E+01	0.0	0.0	0.0	1.133959E+01	-1.081019E+01	1.3E+00
	1.744019E-03	-1.829429E-03	0.0	0.0		1.744019E-03	-1.829429E-03	1.5E+00
40	1.414550E-02	-1.951820E-02	0.0	0.0	0.0	1.414550E-02	-1.951820E-02	1.5E+00
	-7.641124E+00	1.054335E+01	0.0	0.0		1.054335E+01	-7.641124E+00	2.5E+00
41	-7.636874E+00	1.053748E+01	0.0	0.0	0.0	1.053748E+01	-7.636874E+00	2.2E-01
	-1.539817E+01	2.124665E+01	0.0	0.0		2.124665E+01	-1.539817E+01	7.5E-01
42	-1.537781E+01	2.121856E+01	0.0	0.0	0.0	2.121856E+01	-1.537781E+01	1.1E-01
	-1.703890E+01	2.351056E+01	0.0	0.0		2.351056E+01	-1.703890E+01	5.6E-01
43	-1.701903E+01	2.348314E+01	0.0	0.0	0.0	2.348314E+01	-1.701903E+01	1.1E-01
	-1.351106E+01	1.864279E+01	0.0	0.0		1.864279E+01	-1.351106E+01	5.9E-01
44	-1.349238E+01	1.861701E+01	0.0	0.0	0.0	1.861701E+01	-1.349238E+01	4.0E-01
	-1.775586E-02	2.449983E-02	0.0	0.0		2.449983E-02	-1.775586E-02	1.0E+00
45	-6.906726E-04	7.244970E-04	0.0	0.0	0.0	7.244970E-04	-6.906726E-04	6.0E-01
	-1.548697E+01	1.624542E+01	0.0	0.0		1.624542E+01	-1.548697E+01	7.4E-01
46	-1.549035E+01	1.624896E+01	0.0	0.0	0.0	1.624896E+01	-1.549035E+01	9.0E-02
	-2.273416E+01	2.384752E+01	0.0	0.0		2.384752E+01	-2.273416E+01	1.9E-01
47	-2.274072E+01	2.385441E+01	0.0	0.0	0.0	2.385441E+01	-2.274072E+01	3.1E-02
	-2.404834E+01	2.522606E+01	0.0	0.0		2.522606E+01	-2.404834E+01	1.2E-01
48	-2.405744E+01	2.523561E+01	0.0	0.0	0.0	2.523561E+01	-2.405744E+01	3.0E-02
	-1.875231E+01	1.967067E+01	0.0	0.0		1.967067E+01	-1.875231E+01	1.2E-01

TABLE A-7. HEGS-10 FLOOR ANALYSIS (continued)

HEGS-10 GONDOLA
RUN 3.01, FLOOR GRID, LIMIT LOAD, 60-40 DIST., 960 PSF

SUBCASE 1

S T R E S S E S   I N   B A R   E L E M E N T S   (C B A R)

ELEMENT ID.	SA1 / SB1	SA2 / SB2	SA3 / SB3	SA4 / SB4	AXIAL STRESS	SA-MAX / SB-MAX	SA-MIN / SB-MIN	M.S.-T / M.S.-C
49	-1.876345E+01 1.238275E-02	1.968235E+01 -1.298917E-02	0.0 0.0	0.0 0.0	0.0	1.968235E+01 1.238275E-02	-1.876345E+01 -1.298917E-02	3.2E-01 4.4E-01

FLOOR PLATING

In addition to working as the upper flanges for the floor beams, the floor plating also acts as a member which supports concentrated loads (e.g., wheel loads) and transmits their reactions to the beams. The 3/16-inch plate is both strong and stiff. It can safely support large concentrated loads after small amounts of acceptable plastic deformations occur. For example, Figure A-16 shows the expected load-deflection curves for single wheel and dual wheel loads, each positioned to cause the greatest permanent deformation. The permanent deformation from a load of 8000 pounds from a 150-psi tire is about 0.18 inch for the single wheel case and only 0.12 inch for the dual wheel case. Such deflections (about 1/100 of the span) would be hardly perceptible because they would be the same magnitude as the normal deck irregularities. This favorable behavior occurs because the plate structure assumes a new geometry after deflection which supports the load by efficient, in-plane, membrane action. When a small amount of permanent deformation results from the application of a given load, no further permanent deformation will occur under reapplications of the same load. Reference 12 provides examples of similar floor systems used in modern bridges.

The curves shown in Figure A-16 were deduced from full-scale tests performed at Kaman in 1970 upon a deck of similar construction. Figure A-17 compares the deck that was tested to that used in the gondola.

The actual test results are shown in Figure A-18. The expected curves for the gondola were derived from these test results using the following rationale:

> The plate thicknesses are in the ratio .1875/.250 = .75 and the spans in the ratio 15.02/18.00 = .834. Consider the case in which all dimensions were scaled by the factor .75; then for the same load intensity (pounds/unit area) the deformation would also be scaled by the factor .75 and the load by the factor .75 x .75 = .5625. However, for the gondola the scaled load will be less because of the perforations and the 11% longer (.834/.75 = 1.11) span. Assume that these effects reduce the scale factor for load from .5625 to .35. The curves of Figure A-16 are those of Figure A-18 with the ordinate multiplied by .35 and the abscissa by .75.

SUPERSTRUCTURE ANALYSIS

The structural analysis for the HEGS-10 superstructure was made using the critical loads from Table A-6 and the material properties listed in the Material Properties section of this report. Member sizes, materials, loads, and margins of safety are presented.

AD-A073 554 KAMAN AEROSPACE CORP BLOOMFIELD CT F/G 15/5
DESIGN ASSESSMENT OF ADVANCED TECHNOLOGY LIGHTWEIGHT, LOW-COST --ETC(U)
JUL 79 J D PORTERFIELD DAAK51-78-C-0012
UNCLASSIFIED R-1568 USARTL-TR-79-16 NL

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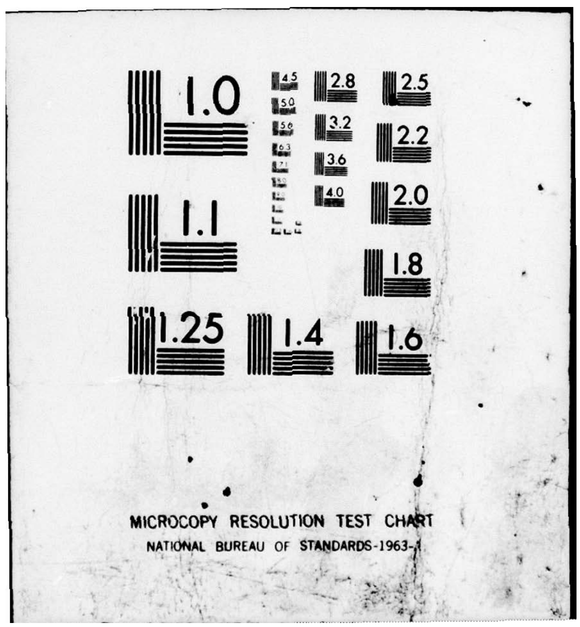

1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
5.6
6.3
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

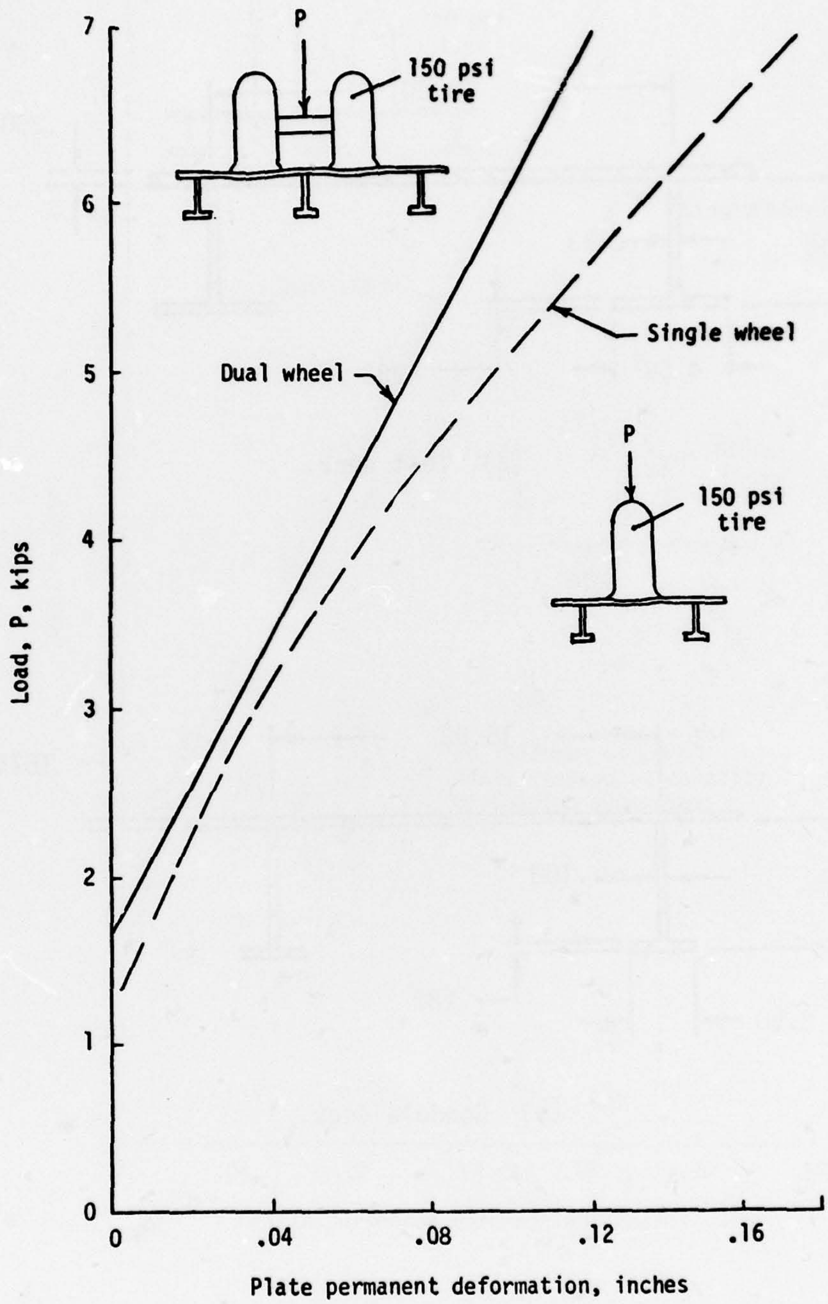
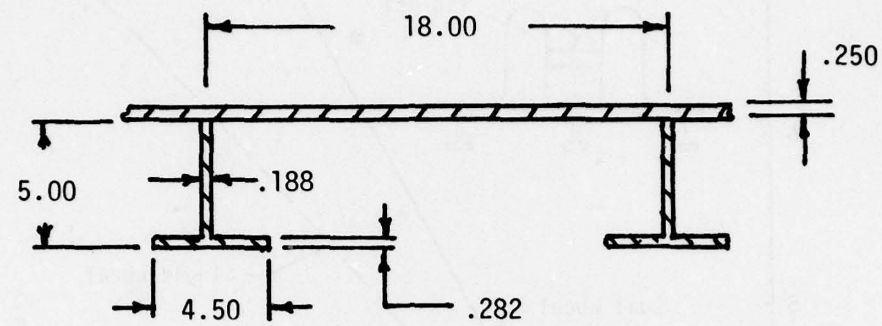
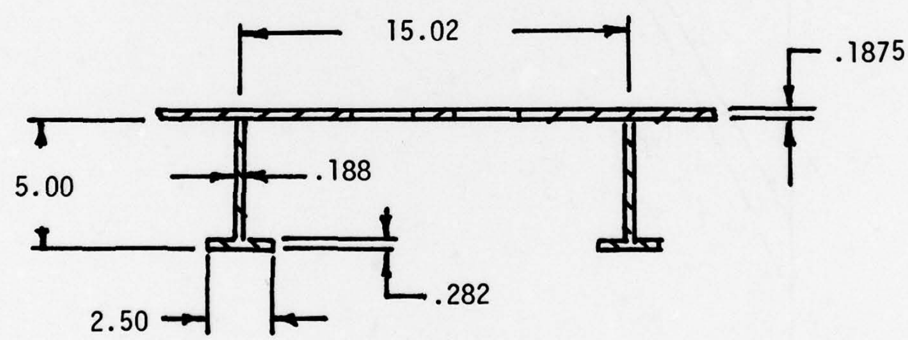


Figure A-16. Expected wheel load vs plate permanent deformation for gondola floor.



(a) Test deck.



(b) Gondola deck.

Figure A-17. Comparison of cross sections for test deck and gondola deck.

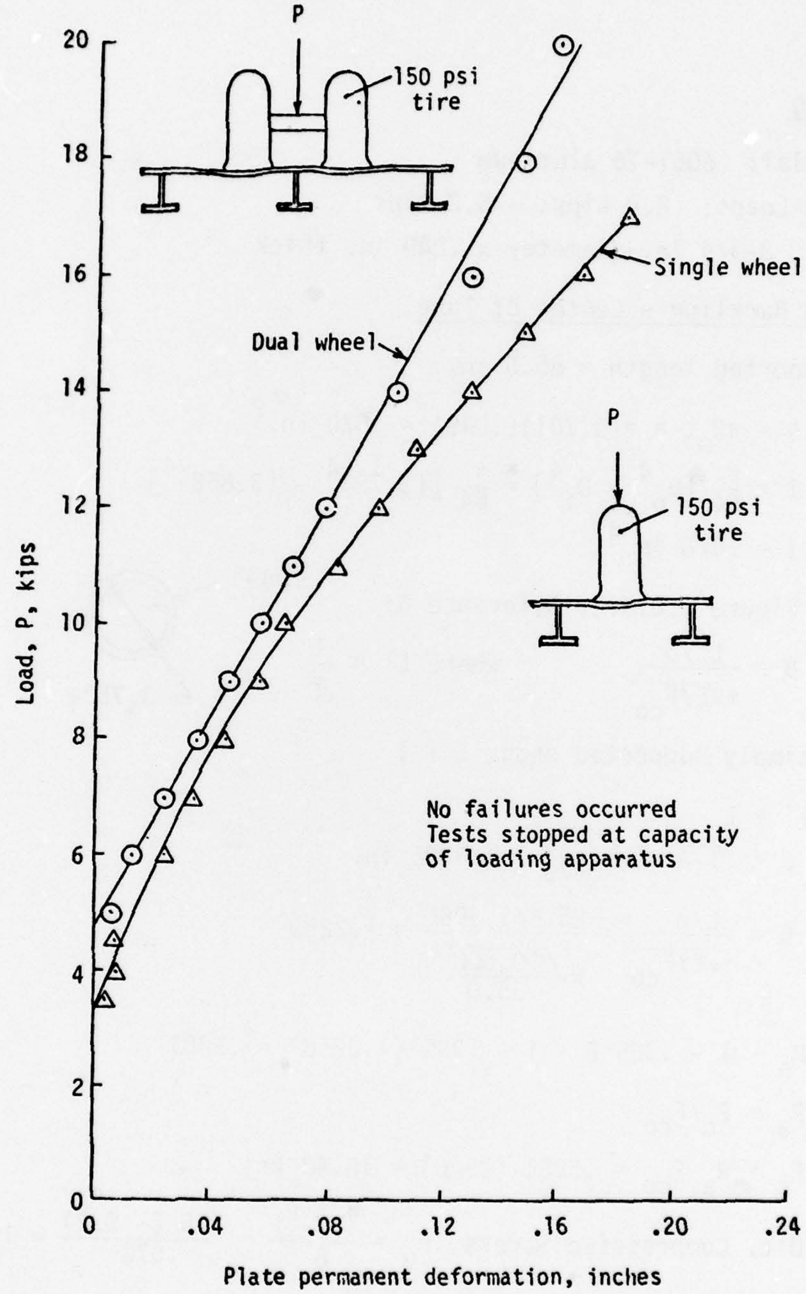


Figure A-18. Wheel load vs plate permanent deformation for test deck defined by Figure A-17.

COLUMNS

Tubing

Material: 6061-T6 aluminum

Limit Loads: 8.0 kips; - 5.2 kips

Size: 3-3/4 in.-diameter x .049 in. thick

Limit Buckling - Center of Tube

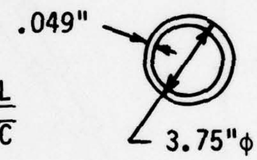
Unsupported length = 85.6 in.

$$A = \pi D_m t = \pi(3.701)(.049) = .570 \text{ in.}^2$$

$$I = \frac{\pi}{64}\left[D_o^{\,4} - D_i^{\,4}\right] = \frac{\pi}{64}\left[(3.75)^4 - (3.652)^4\right]$$

$$I = .976 \text{ in.}^4$$

From Figure 1.6.3.2, Reference 6:



$$B = \frac{L'/\rho}{\pi\sqrt{E/F_{co}}} \qquad \text{where } L' = \frac{L}{\sqrt{C}}$$

For simply supported ends, C = 1

$$L' = L$$

$$\rho = \sqrt{I/A} = \sqrt{\frac{.976}{.570}} = 1.3085 \text{ in.}$$

$$B = \frac{L/\rho}{\pi\sqrt{E/F_{co}}} = \frac{85.6/1.3085}{\pi\sqrt{\frac{10,000}{35.0}}} = 1.2258$$

$$R_a = 1 - .385\,B = 1 - .385\,(1.2258) = .5281$$

$$R_a = F_c/F_{co}$$

$$F_c = R_a\,F_{co} = .5281\,(35.0) = 18.48 \text{ ksi}$$

$$\text{Ult. Compressive Stress, } F_u = \frac{1.5\,P_y}{A} = \frac{1.5\,(-\,5.2)}{.570} = 13.68 \text{ ksi}$$

$$MS_u = \frac{18.48}{13.68} - 1 = \underline{\underline{.35}}$$

Tensile Yield Stress at Tube Ends (Heat-affected Zone)

Limit Tension Load, $P_y = 8.0$ kips

$$f_{ty} = \frac{P_y}{A} = \frac{8.0}{.570} = 14.04 \text{ ksi}$$

$F_{ty} = 20.0$ ksi

$$MS_{ty} = \frac{20.0}{14.04} - 1 = \underline{\underline{.42}}$$

Tensile Ultimate Stress at Tube Ends (Heat-affected Zone)

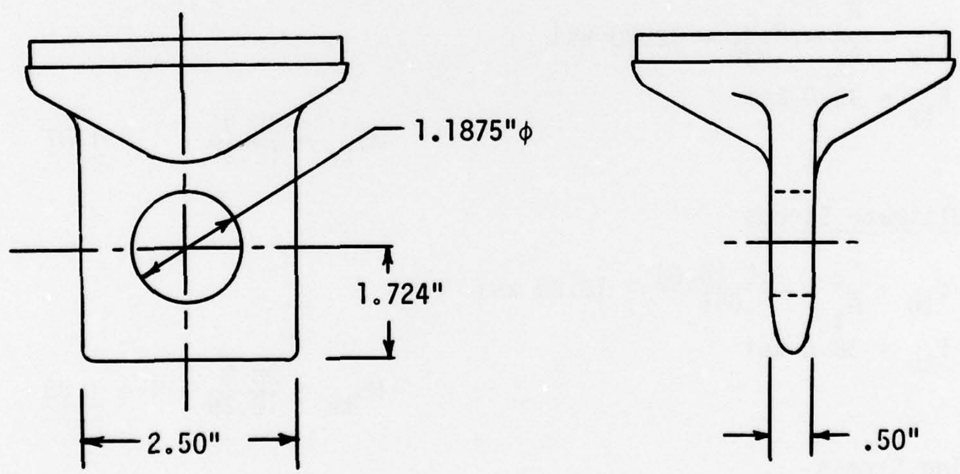
Ultimate Tension Load, $P_u = 1.5\ P_y = 1.5\ (8.0) = 12.0$ kips

$$f_{tu} = \frac{P_u}{A} = \frac{12.0}{.570} = 21.05 \text{ ksi}$$

$F_{tu} = 24.0$ ksi

$$MS_{tu} = \frac{24.0}{21.05} - 1 = \underline{\underline{.14}}$$

End Lugs



Material: 6061-T6 aluminum forging

Limit Load: 8.0 kips

Shearout

$A_s = 2\ (1.130)(.50) = 1.130\ \text{in.}^2$

Yield Shear Stress

$$f_{sy} = \frac{P_y}{A_s} = \frac{8.0}{1.130} = 7.08 \text{ ksi}$$

$$F_{sy} = 20.0 \text{ ksi}$$

$$MS_{sy} = \frac{20.0}{7.08} - 1 = \underline{\underline{1.82}}$$

Ultimate Shear Stress

$$f_s = \frac{P_u}{A_s} = \frac{1.5\ (8.0)}{1.130} = 10.62 \text{ ksi}$$

$$F_{su} = 25.0 \text{ ksi}$$

$$MS_{su} = \frac{25.0}{10.62} - 1 = \underline{\underline{1.35}}$$

Tensile Stress

$$A_t = 1.3125\ (.50) = .656 \text{ in.}^2$$

Yield Stress

$$f_{ty} = \frac{P_y}{A_t} = \frac{8.0}{.656} = 12.20 \text{ ksi}$$

$$F_{ty} = 35.0 \text{ ksi}$$

$$MS_{ty} = \frac{35.0}{12.20} - 1 = \underline{\underline{1.87}}$$

Ultimate Stress

$$f_{tu} = \frac{P_u}{A_t} = \frac{1.5\ (8.0)}{.656} = 18.29 \text{ ksi}$$

$$F_{tu} = 38.0 \text{ ksi}$$

$$MS_{tu} = \frac{38.0}{18.29} - 1 = \underline{\underline{1.08}}$$

Bearing Stress

$$A_{br} = 1.1875\ (.5) = .594 \text{ in.}^2$$

Bearing Yield Stress

Limit Load = 8.0 kips

$$f_{bry} = \frac{P_y}{A_{br}} = \frac{8.0}{.594} = 13.47 \text{ ksi}$$

$$F_{bry} = 61 \text{ ksi}$$

$$MS_{bry} = \frac{61.0}{13.47} - 1 = \underline{\underline{3.53}}$$

Bearing Ultimate Stress

Ultimate Load, $P_u = 1.5\ (8.0) = 12.0$ kips

$$f_{bru} = \frac{P_u}{A_{br}} = \frac{12.0}{.594} = 20.20 \text{ ksi}$$

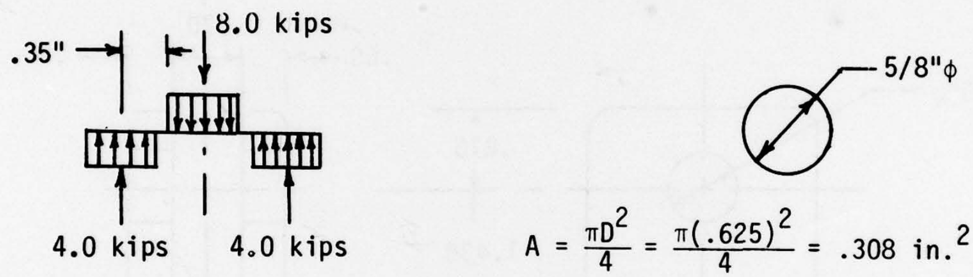
$F_{bru} = 76.0$ ksi

$$MS_{bru} = \frac{76.0}{20.20} - 1 = \underline{2.76}$$

Column Attachment Bolt

Material: Alloy Steel, $F_{tu} = 125$ ksi

Limit Load = 8.0 kips



$$A = \frac{\pi D^2}{4} = \frac{\pi(.625)^2}{4} = .308 \text{ in.}^2$$

$$I = \frac{\pi D^4}{64} = \frac{\pi(.625)^4}{64} = .00749 \text{ in.}^2$$

Bending Yield Stress

$M = 4.0\ (.35) = 1.40$ kips

$$f_{by} = \frac{Mc}{I} = \frac{1.40\ (.3125)}{.00749} = 58.40 \text{ ksi}$$

$F_{ty} = 103.0$ ksi

$$MS_{by} = \frac{103.0}{58.40} - 1 = \underline{.76}$$

Bending Ultimate Stress

$f_{bu} = 1.5\ f_{by} = 1.5\ (58.40) = 87.6$ ksi

$F_{bu} = 125.0$ ksi

$$MS_{bu} = \frac{125.0}{87.6} - 1 = \underline{.43}$$

Ultimate Shear Stress

$$A_s = 2\ (.308) = .616\ \text{in.}^2$$

$$f_{su} = \frac{P_{su}}{A_s} = \frac{1.5\ (8.0)}{.616} = 19.48\ \text{ksi}$$

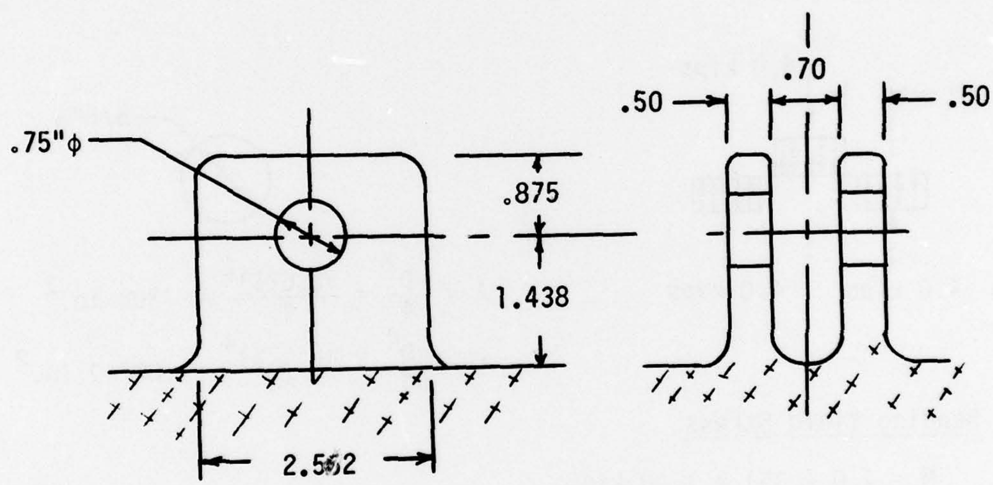
$$F_{su} = 75.0\ \text{ksi}$$

$$MS_{su} = \frac{75.0}{19.48} - 1 = \underline{\underline{2.85}}$$

Column Attachment Clevis on Corner Fittings

Material: 6066-T6 aluminum forging

Limit Load: 8.0 kips



Shearout

$$A_s = 4\ (5.0)(5.0) = 1.0\ \text{in.}^2$$

Shear Yield Stress

$$f_{sy} = \frac{P_y}{A_s} = \frac{8.0}{1.0} = 8.0\ \text{ksi}$$

$$F_{sy} = 27.0\ \text{ksi}$$

$$MS_{sy} = \frac{27.0}{8.0} - 1 = \underline{\underline{2.38}}$$

Shear Ultimate Stress

$f_{su} = 1.5\ f_{sy} = 1.5\ (8.0) = 12.0$ ksi

$F_{su} = 34.0$ ksi

$$MS_{su} = \frac{34.0}{12.0} - 1 = \underline{\underline{1.83}}$$

Ultimate Tensile Stress

$A_t = 2\ (1.812)(.5) = 1.812$ in.^{2}

$$f_{tu} = \frac{P_u}{A_t} = \frac{1.5\ (8.0)}{1.812} = 6.62 \text{ ksi}$$

$F_{tu} = 50.0$ ksi

$$MS_{tu} = \frac{50.0}{6.62} - 1 = \underline{\underline{6.55}}$$

Ultimate Bearing Stress

$A_{br} = 2\ (.75)(.5) = .75$ in.^{2}

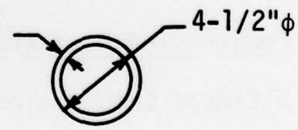
$$f_{bru} = \frac{P_u}{A_{br}} = \frac{1.5\ (8.0)}{.75} = 16.0 \text{ ksi}$$

$F_{bru} = 78.0$ ksi

$$MS_{bru} = \frac{78.0}{16.0} - 1 = \underline{\underline{3.88}}$$

UPPER STRUCTURE

Upper Sides



Material: 6061-T6 aluminum tubing

Limit Load: - 5.6 kips

Size: 4-1/2 in. diam x .049 in. thick x 104.13 in. long

$A = \pi D_m t = \pi(4.451)(.049) = .685$ in.^{2}

$$I = \frac{\pi}{64}\left[D_o^{\,4} - D_i^{\,4}\right] = \frac{\pi}{64}\left[(4.5)^4 - (4.402)^4\right] = 1.697 \text{ in.}^4$$

Buckling - Center of Tube

Assume ends are simply supported

From Figure 1.6.3.2, Reference 6:

$$B = \frac{L'/\rho}{\pi\sqrt{E/F_{co}}} \qquad \text{where } L' = \frac{L}{\sqrt{C}} \qquad \text{For } C = 1,\ L' = L$$

$$\rho = \sqrt{I/A} = \sqrt{\frac{1.697}{.685}} = 1.574 \text{ in.}$$

$$B = \frac{104.13/1.574}{\pi\sqrt{\frac{10,100}{35.0}}} = 1.239$$

$$R_a = 1 - .385\ B = 1 - .385\ (1.239) = .523$$

$$F_c = R_a\ F_{co} = .523\ (35.0) = 18.30 \text{ ksi}$$

Ult. Compressive Stress, $f_u = \dfrac{1.5\ P_y}{A} = \dfrac{1.5\ (-\ 5.6)}{.685} = 12.26$

$$MS_u = \frac{18.30}{12.26} - 1 = \underline{\underline{.49}}$$

Compression Yield Stress at Tube Ends (Heat-affected Zone)

Limit Compression Load, $P_y = -\ 5.6$ kips

$$f_{cy} = \frac{P_y}{A} = \frac{-\ 5.6}{.685} = 8.18 \text{ ksi}$$

$$F_{cy} = 20.0 \text{ ksi}$$

$$MS_{cy} = \frac{20.0}{8.18} - 1 = \underline{\underline{1.44}}$$

Compression Ultimate Stress at Tube Ends (Heat-affected Zone)

Ultimate Compression Load, $P_u = 1.5\ P_y = 1.5\ (-\ 5.6) = 8.40$ kips

$$f_{cu} = \frac{P_u}{A} = \frac{8.40}{.685} = 12.26 \text{ ksi}$$

$$F_{cu} = 24.0 \text{ ksi}$$

$$MS_{cu} = \frac{24.0}{12.26} - 1 = \underline{\underline{.96}}$$

Upper Ends

Material: 6061-T6 aluminum tubing

Limit Load: - 7.2 kips

Size: 4-1/2 in. diam x .049 in. thick x 82.5 in. long

Buckling - Center of Tube

$A = .685 \text{ in.}^2 \qquad I = 1.697 \text{ in.}^4 \qquad \rho = 1.574 \text{ in.} \qquad C = 1$

From Figure 1.6.3.2, Reference 6:

$$B = \frac{L'/\rho}{\pi\sqrt{E/F_{co}}} = \frac{82.5/1.514}{\pi\sqrt{\frac{10,100}{35.0}}} = .982$$

$$R_a = 1 - .385\ B = 1 - .385\ (.982) = .622$$

$$F_c = R_a\ F_{co} = .622\ (35.0) = 21.77 \text{ ksi}$$

$$\text{Ult. Compressive Stress} = \frac{1.5\ P_y}{A} = \frac{1.5\ (-\ 7.2)}{.685} = 15.77 \text{ ksi}$$

$$MS_u = \frac{21.77}{15.77} - 1 = \underline{\underline{.38}}$$

Compression Yield Stress at Tube Ends (Heat-affected Zone)

Limit Load, $P_y = -\ 7.2$ kips

$$f_{cy} = \frac{P_y}{A} = \frac{-\ 7.2}{.685} = 10.51 \text{ ksi}$$

$$F_{cy} = 20.0 \text{ ksi}$$

$$MS_{cy} = \frac{20.0}{10.51} - 1 = \underline{\underline{.90}}$$

Compression Ultimate Stress at Tube Ends (Heat-affected Zone)

Ultimate Load, $P_u = 1.5\ P_y = 1.5\ (-\ 7.2) = -\ 10.8$ kips

$$f_{cu} = \frac{P_u}{A} = \frac{-\ 10.8}{.685} = 15.77 \text{ ksi}$$

$$F_{cu} = 24.0 \text{ ksi}$$

$$MS_{cu} = \frac{2.40}{15.77} - 1 = \underline{\underline{.52}}$$

DIAGONALS

The diagonal assembly consists of Kevlar cables with 17-4PH stainless steel end fittings. The same size cable is used for the top, side, and end diagonals.

Cable

Material: Kevlar

Limit Loads: Top Diagonals = 1.0 kip

Side Diagnoals = 10.3 kips

End Diagonals = 7.0 kips

Size: PS29-6 x 19 x .51

Minimum Breaking Strength of Cable = 22.0 kips

End Fitting Efficiency = 75%

Ultimate Cable Strength = .75 (22.0) = 16.5 kips

Top Diagonals: $MS_{tu} = \frac{16.5}{1.5\ (1.0)} - 1 = \underline{\underline{10.0}}$

Side Diagonals: $MS_{tu} = \frac{16.5}{1.5\ (10.3)} - 1 = \underline{\underline{.07}}$

End Diagonals: $MS_{tu} = \frac{16.5}{1.5\ (7.0)} - 1 = \underline{\underline{.57}}$

FLOOR-BEAM GRID

The floor of the HEGS-20 is supported at its four corners and also at the midspans of the long sides. Figure A-19 shows the main structural beams of the floor. These beams are created by welding T-sections and angle-sections to the plate which forms the surface of the floor; thus, the floor surface itself becomes an integral part of the beams. There are:

1. Six longitudinal beams which support interior loads
2. Three lateral beams which support the longitudinal beams and transfer load to the reaction points
3. Two lateral beams which interconnect the longitudinal beams at their sub-midspans.

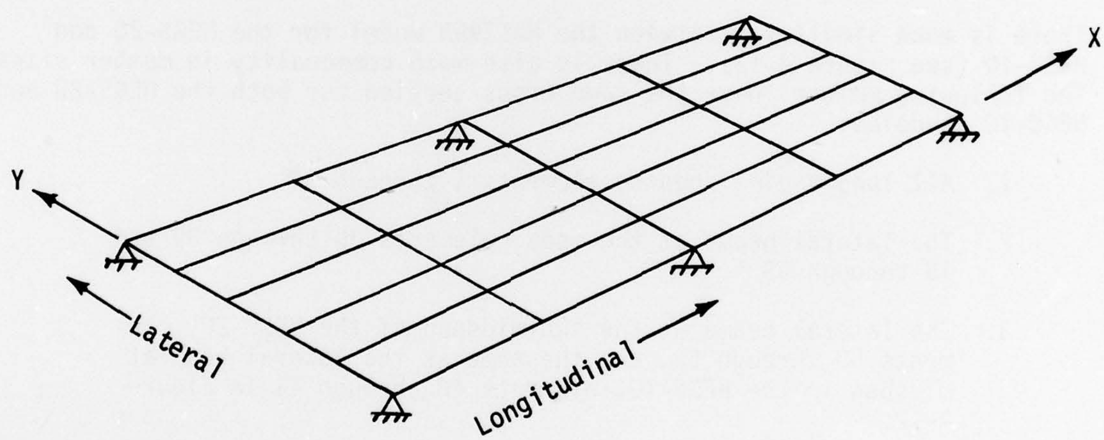


Figure A-19. Main floor-beam grid for HEGS-20.

The structural integrity of the floor-beam grid was analyzed using NASTRAN. Figure A-20 shows the structural model with numbered nodes and elements. Element numbers are circled.

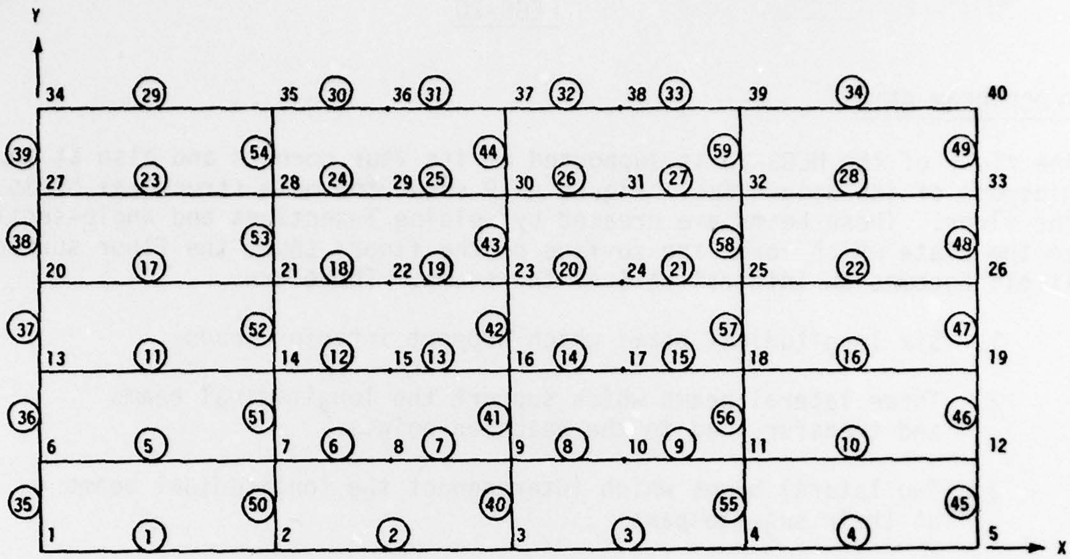


Figure A-20. NASTRAN model for floor-beam grid of HEGS-20.

There is much similarity between the NASTRAN model for the HEGS-20 and HEGS-10 (see Figure A-12). There is also much commonality in member sizes. The following members have the same cross section for both the HEGS-20 and HEGS-10 gondolas:

1. All longitudinal beams, elements 1 through 34

2. The lateral beams at the ends, elements 35 through 39 and 45 through 49

3. The lateral beams at the sub-midspan of the HEGS-20, elements 50 through 59, are the same as the lateral beam at midspan in the HEGS-10, elements 40 through 44 in Figure A-12.

The section properties and cross sections for the common elements are presented in Figure A-13. Similar data for the new member at the center of the HEGS-20 are shown in Figure A-21.

The NASTRAN analysis presented herein corresponds to an off-center load of 25,000 pounds at 1-g. Using a limit load factor of 2.3, the applied load for the analysis is 25 x 2.3 - 57.5 kips (limit). The centroid of the load lies at the geometrical 60% position of the floor in the longitudinal and lateral directions as shown in Figure A-22. The load corresponds to 300 psf at 1-g, 690 psf at limit, and 1035 psf at ultimate.

Members 40 through 44

Center beam

$A = 9.647 \text{ in.}^2$

$I_y = 51.544 \text{ in.}^4$

$A_{web}/A_{total} = .219$

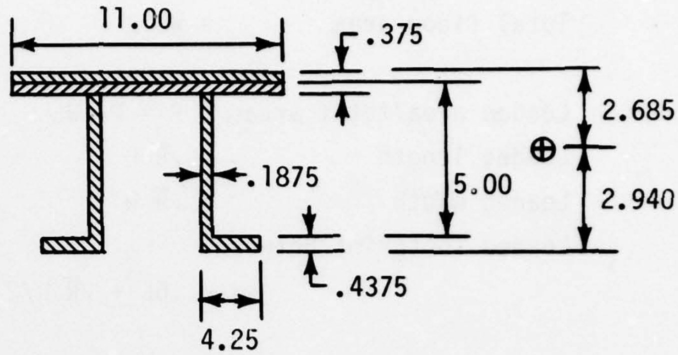


Figure A-21. Section properties and cross section for center beam element of HEGS-20.

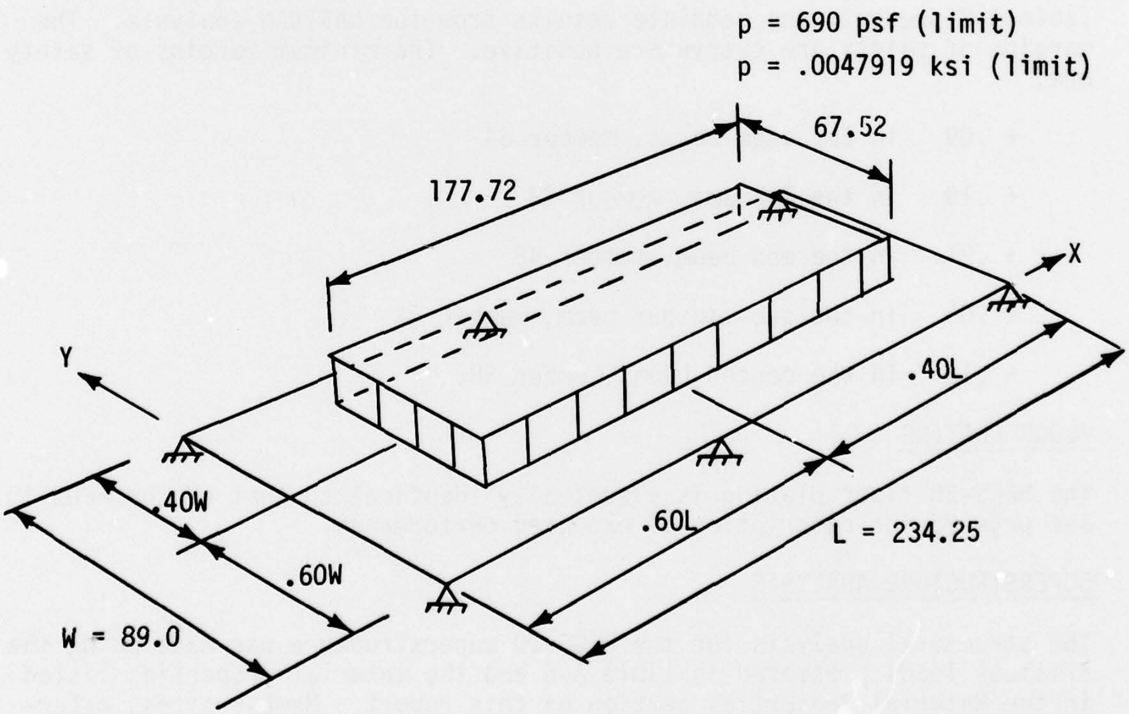


Figure A-22. Loading for HEGS-20, case 3.01.

The calculations to determine the loaded area are:

Intensity of load	= p	= 300 psf (at 1-g)
Footprint of load	= P/p	= 25/.3 = 83.33 sq. ft.
Total floor area	= WL	= 234.25 x 89/144
		= 144.78 sq. ft.
Loaded area/total area	= R = P/pWL	= 83.33/144.78 = .57556
Loaded length	= $\sqrt{R}$ L	= $\sqrt{.57556}$ x 234.25 = 177.72 in.
Loaded width	= $\sqrt{R}$ W	= $\sqrt{.57556}$ x 89.00 = 67.52 in.
Loaded footprint between:		
	x = .6L $\pm$ $\sqrt{R}$ L/2	= 140.55 $\pm$ 177.72/2;
		51.69 to 229.41 in.
	y = .6L $\pm$ $\sqrt{R}$ W/2	= 53.40 $\pm$ 67.52/2;
		19.64 to 87.16 in.

The corresponding loads acting upon the longitudinal beams of the NASTRAN model are calculated in Figure A-23.

Table A-8 presents the complete results from the NASTRAN analysis. The margins of safety are everywhere positive. The minimum margins of safety are:

+ .09 in the edge beams, member 34

+ .19 in the T-beams, member 28

+ .21 in the end beam, member 48

+ .05 in the sub-midspan beam, member 43

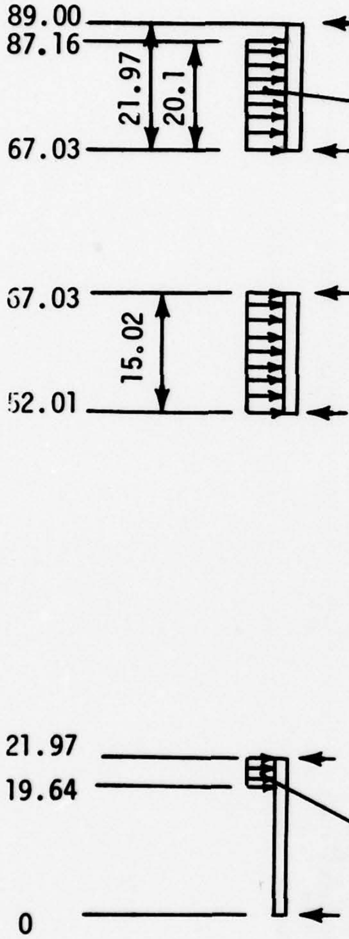
+ .18 in the center beam, member 58.

FLOOR PLATING

The HEGS-20 floor plating is essentially identical to that of the HEGS-10. See page 96 for description of expected performance.

SUPERSTRUCTURE ANALYSIS

The structural analysis for the HEGS-20 superstructure was made using the critical loads presented in Table A-6 and the material properties listed in the Material Properties section of this report. Member sizes, materials, loads, and margins of safety are presented (see page 127).



$$.09632 \times \frac{20.1}{2 \times 21.97} = .04406 \text{ k/in.}$$

total load = 20.1 x .0047919 = .09632 k/in.

.09632 - .04406 = .05226 k/in.

$$\begin{array}{r} .05226 \\ + .03599 \\ \hline .08825 \end{array} \text{ k/in.}$$

$$\frac{15.02 \times .0047919}{2} = .03599 \text{ k/in.}$$

.03599

$$\begin{array}{r} .03599 \\ \times 2 \\ \hline .07198 \end{array} \text{ k/in.}$$

$$\begin{array}{r} .03599 \\ + .01058 \\ \hline .04657 \end{array} \text{ k/in.}$$

(.01117 - .00059) = .01058 k/in.

total load = (21.97 - 19.64) x .0047919
= .01117 k/in.

$$.01117 \times \frac{(21.97 - 19.64)}{2 \times 21.97} = .00059 \text{ k/in.}$$

Figure A-23. Loadings on beams of HEGS-20, case 3.01.

TABLE A-8. HEGS-20 FLOOR ANALYSIS

```
N A S T R A N   E X E C U T I V E   C O N T R O L   D E C K   E C H O

ID KAMAN, GONDOLA
SOL 1
TIME 2
DIAG 8.13.16
CEND

                          C A S E   C O N T R O L   D E C K   E C H O

   CARD
   COUNT
     1      TITLE = HEGS-20 GONDOLA
     2      SUBCASE 1
     3          SUBTITLE = RUN 3.01, FLOOR GRID, LIMIT LOAD, 60-40 DIST., 690 PSF
     4          LOAD = 201
     5          DISP = ALL
     6          ELFO = ALL
     7          STRESS = ALL
     8          OLOAD = ALL
     9          SPCFORCES = ALL
    10      BEGIN BULK
           TOTAL COUNT=  163
```

TABLE A-8. HEGS-20 FLOOR ANALYSIS (continued)

HEGS-20 GONDOLA

SORTED BULK DATA ECHO

CARD COUNT	. 1 ..	2 ..	3 ..	4 ..	5 ..	6 ..	7 ..	8 ..	9 ..	10 .
1-	CBAR	1	1	1	2	6			2	BC11
2-	+C11	5								
3-	CBAR	2	1	2	3	7			2	
4-	CBAR	3	1	3	4	9			2	
5-	CBAR	4	1	4	5	11			2	BC41
6-	+C41		5							
7-	CBAR	5	2	6	7	13			2	BC51
8-	+C51	4								
9-	CBAR	6	2	7	8	14			2	
10-	CBAR	7	2	8	9	15			2	
11-	CBAR	8	2	9	10	16			2	
12-	CBAR	9	2	10	11	17			2	
13-	CBAR	10	2	11	12	18			2	BC101
14-	+C101		5							
15-	CBAR	11	2	13	14	20			2	BC111
16-	+C111	5								
17-	CBAR	12	2	14	15	21			2	
18-	CBAR	13	2	15	16	22			2	
19-	CBAR	14	2	16	17	23			2	
20-	CBAR	15	2	17	18	24			2	
21-	CBAR	16	2	18	19	25			2	BC161
22-	+C161		5							
23-	CBAR	17	2	20	21	27			2	BC171
24-	+C171	5								
25-	CBAR	18	2	21	22	28			2	
26-	CBAR	19	2	22	23	29			2	
27-	CBAR	20	2	23	24	30			2	
28-	CBAR	21	2	24	25	31			2	
29-	CBAR	22	2	25	26	32			2	BC221
30-	+C221		5							
31-	CBAR	23	2	27	28	34			2	BC231
32-	+C231	5								
33-	CBAR	24	2	28	29	35			2	
34-	CBAR	25	2	29	30	36			2	
35-	CBAR	26	2	30	31	37			2	
36-	CBAR	27	2	31	32	38			2	
37-	CBAR	28	2	32	33	39			2	BC281
38-	+C281		5							
39-	CBAR	29	1	34	35	200.	200.	.0	1	BC291
40-	+C291	5								
41-	CBAR	30	1	35	36	200.	200.	.0	1	
42-	CBAR	31	1	36	37	200.	200.	.0	1	
43-	CBAR	32	1	37	38	200.	200.	.0	1	
44-	CBAR	33	1	38	39	200.	200.	.0	1	
45-	CBAR	34	1	39	40	200.	200.	.0	1	BC341
46-	+C341		5							
47-	CBAR	35	3	1	6	-100.	200.	.0	1	
48-	CBAR	36	3	6	13	-100.	200.	.0	1	
49-	CBAR	37	3	13	20	-100.	200.	.0	1	
50-	CBAR	38	3	20	27	-100.	200.	.0	1	

TABLE A-8. HEGS-20 FLOOR ANALYSIS (continued)

HEGS-20 GONDOLA

SORTED BULK DATA ECHO

CARD COUNT	1	2	3	4	5	6	7	8	9	10
51-	CBAR	39	3	27	34	-100.	200.	.0	1	
52-	CBAR	40	5	3	9	1			2	
53-	CBAR	41	5	9	16	6			2	
54-	CBAR	42	5	16	23	13			2	
55-	CBAR	43	5	23	30	20			2	
56-	CBAR	44	5	30	37	27			2	
57-	CBAR	45	3	5	12	3			2	
58-	CBAR	46	3	12	19	9			2	
59-	CBAR	47	3	19	26	16			2	
60-	CBAR	48	3	26	33	23			2	
61-	CBAR	49	3	33	40	30			2	
62-	CBAR	50	4	2	7	1			2	
63-	CBAR	51	4	7	14	6			2	
64-	CBAR	52	4	14	21	13			2	
65-	CBAR	53	4	21	28	20			2	
66-	CBAR	54	4	28	35	27			2	
67-	CBAR	55	4	4	11	3			2	
68-	CBAR	56	4	11	18	9			2	
69-	CBAR	57	4	18	25	16			2	
70-	CBAR	58	4	25	32	23			2	
71-	CBAR	59	4	32	39	30			2	
72-	GRID	1		.0	.0	.0		1263		
73-	GRID	2		58.56	.0	.0		126		
74-	GRID	3		117.12	.0	.0		1263		
75-	GRID	4		175.69	.0	.0		126		
76-	GRID	5		234.25	.0	.0		1263		
77-	GRID	6		.0	21.97	.0		126		
78-	GRID	7		58.56	21.97	.0		126		
79-	GRID	8		87.84	21.97	.0		126		
80-	GRID	9		117.12	21.97	.0		126		
81-	GRID	10		146.40	21.97	.0		126		
82-	GRID	11		175.68	21.97	.0		126		
83-	GRID	12		234.25	21.97	.0		126		
84-	GRID	13		.0	36.99	.0		126		
85-	GRID	14		58.56	36.99	.0		126		
86-	GRID	15		87.84	36.99	.0		126		
87-	GRID	16		117.12	36.99	.0		126		
88-	GRID	17		146.40	36.99	.0		126		
89-	GRID	18		175.68	36.99	.0		126		
90-	GRID	19		234.25	36.99	.0		126		
91-	GRID	20		.0	52.01	.0		126		
92-	GRID	21		58.56	52.01	.0		126		
93-	GRID	22		87.84	52.01	.0		126		
94-	GRID	23		117.12	52.01	.0		126		
95-	GRID	24		146.40	52.01	.0		126		
96-	GRID	25		175.68	52.01	.0		126		
97-	GRID	26		234.25	52.01	.0		126		
98-	GRID	27		.0	67.03	.0		126		
99-	GRID	28		58.56	67.03	.0		126		
100-	GRID	29		87.84	67.03	.0		126		

TABLE A-8. HEGS-20 FLOOR ANALYSIS (continued)

HEGS-20 GONDOLA

SORTED BULK DATA ECHO

CARD COUNT	1	2	3	4	5	6	7	8	9	10
101-	GRID	30		117.12	67.03	.0		126		
102-	GRID	31		146.40	67.03	.0		126		
103-	GRID	32		175.68	67.03	.0		126		
104-	GRID	33		234.25	67.03	.0		126		
105-	GRID	34		.0	89.00	.0		1263		
106-	GRID	35		58.56	89.00	.0		126		
107-	GRID	36		87.84	89.00	.0		126		
108-	GRID	37		117.12	89.00	.0		1263		
109-	GRID	38		146.40	89.00	.0		126		
110-	GRID	39		175.68	89.00	.0		126		
111-	GRID	40		234.25	89.00	.0		1263		
112-	MAT1	1	10400.	4000.						MA11
113-	+A11	26.0	27.0	15.						
114-	PBAR	1	1	3.375	1.	14.143	.1			PB11
115-	+B11	.0	2.562	.0	-2.625					PB12
116-	+B12	.480	.480							
117-	PBAR	2	1	2.904	1.	13.331	.1			PB21
118-	+B21	.0	2.046	.0	-3.142					PB22
119-	+B22	.336	.336							
120-	PBAR	3	1	4.197	1.	18.340	.1			PB31
121-	+B31	.0	2.532	.0	-2.656					PB32
122-	+B32	.386	.386							
123-	PBAR	4	1	2.717	1.	12.563	.1			PB41
124-	+B41	.0	2.180	.0	-3.008					PB42
125-	+B42	.359	.359							
126-	PBAR	5	1	9.647	1.	51.54	.1			PB51
127-	+B51	.0	2.685	.0	-2.940					PB52
128-	+B52	.219	.219							
129-	PLOAD1	201	1	FZ	FR	.894	-.00059	1.00	-.00059	
130-	PLOAD1	201	2	FZ	FR	.000	-.00059	1.00	-.00059	
131-	PLOAD1	201	3	FZ	FR	.000	-.00059	1.00	-.00059	
132-	PLOAD1	201	4	FZ	FR	.000	-.00059	.915	-.00059	
133-	PLOAD1	201	5	FZ	FR	.894	-.04657	1.00	-.04657	
134-	PLOAD1	201	6	FZ	FR	.000	-.04657	1.00	-.04657	
135-	PLOAD1	201	7	FZ	FR	.000	-.04657	1.00	-.04657	
136-	PLOAD1	201	8	FZ	FR	.000	-.04657	1.00	-.04657	
137-	PLOAD1	201	9	FZ	FR	.000	-.04657	1.00	-.04657	
138-	PLOAD1	201	10	FZ	FR	.000	-.04657	.915	-.04657	
139-	PLOAD1	201	11	FZ	FR	.894	-.07198	1.00	-.07198	
140-	PLOAD1	201	12	FZ	FR	.000	-.07198	1.00	-.07198	
141-	PLOAD1	201	13	FZ	FR	.000	-.07198	1.00	-.07198	
142-	PLOAD1	201	14	FZ	FR	.000	-.07198	1.00	-.07198	
143-	PLOAD1	201	15	FZ	FR	.000	-.07198	1.00	-.07198	
144-	PLOAD1	201	16	FZ	FR	.000	-.07198	.915	-.07198	
145-	PLOAD1	201	17	FZ	FR	.894	-.07198	1.00	-.07198	
146-	PLOAD1	201	18	FZ	FR	.000	-.07198	1.00	-.07198	
147-	PLOAD1	201	19	FZ	FR	.000	-.07198	1.00	-.07198	
148-	PLOAD1	201	20	FZ	FR	.000	-.07198	1.00	-.07198	
149-	PLOAD1	201	21	FZ	FR	.000	-.07198	1.00	-.07198	
150-	PLOAD1	201	22	FZ	FR	.000	-.07198	.915	-.07198	

TABLE A-8. HEGS-20 FLOOR ANALYSIS (continued)

HEGS-20 GONDOLA

S O R T E D   B U L K   D A T A   E C H O

CARD COUNT	. 1 ..	2 ..	3 ..	4 ..	5 ..	6 ..	7 ..	8 ..	9 ..	10 .
151-	PLOAD1	201	23	FZ	FR	.894	-.08825	1.00	-.08825	
152-	PLOAD1	201	24	FZ	FR	.000	-.08825	1.00	-.08825	
153-	PLOAD1	201	25	FZ	FR	.000	-.08825	1.00	-.08825	
154-	PLOAD1	201	26	FZ	FR	.000	-.08825	1.00	-.08825	
155-	PLOAD1	201	27	FZ	FR	.000	-.08825	.915	-.08825	
156-	PLOAD1	201	28	FZ	FR	.894	-.04406	1.00	-.04406	
157-	PLOAD1	201	29	FZ	FR	.000	-.04406	1.00	-.04406	
158-	PLOAD1	201	30	FZ	FR	.000	-.04406	1.00	-.04406	
159-	PLOAD1	201	31	FZ	FR	.000	-.04406	1.00	-.04406	
160-	PLOAD1	201	32	FZ	FR	.000	-.04406	1.00	-.04406	
161-	PLOAD1	201	33	FZ	FR	.000	-.04406	1.00	-.04406	
162-	PLOAD1	201	34	FZ	FR	.000	-.04406	.915	-.04406	
	ENDDATA									

TOTAL COUNT= 162

TABLE A-8. HEGS-20 FLOOR ANALYSIS (continued)

HEGS-20 GONDOLA
RUN 3.01, FLOOR GRID, LIMIT LOAD, 60-40 DIST., 690 PSF

SUBCASE 1

D I S P L A C E M E N T   V E C T O R

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
1	G	0.0	0.0	0.0	-2.320647E-03	6.503554E-03	0.0
2	G	0.0	0.0	-1.060681E-01	-1.274487E-02	-1.514118E-03	0.0
3	G	0.0	0.0	0.0	-2.235470E-02	3.111209E-03	0.0
4	G	0.0	0.0	-3.541262E-01	-2.422269E-02	1.533802E-03	0.0
5	G	0.0	0.0	0.0	-2.154164E-02	0.0	0.0
6	G	0.0	0.0	-4.793398E-02	-1.674930E-03	6.503554E-03	0.0
7	G	0.0	0.0	-3.731088E-01	-9.710781E-03	3.487239E-03	0.0
8	G	0.0	0.0	-4.315391E-01	-1.302481E-02	1.053056E-03	0.0
9	G	0.0	0.0	-4.818330E-01	-1.633884E-02	5.035520E-03	0.0
10	G	0.0	0.0	-7.166379E-01	-1.779621E-02	7.682810E-03	0.0
11	G	0.0	0.0	-8.650767E-01	-1.925359E-02	1.240238E-03	0.0
12	G	0.0	0.0	-4.462866E-01	-1.573401E-02	0.0	0.0
13	G	0.0	0.0	-6.633649E-02	-6.445455E-04	6.503554E-03	0.0
14	G	0.0	0.0	-4.871632E-01	-4.457268E-03	5.424043E-03	0.0
15	G	0.0	0.0	-5.981417E-01	-5.429294E-03	2.271455E-03	0.0
16	G	0.0	0.0	-6.713472E-01	-6.401321E-03	6.095994E-03	0.0
17	G	0.0	0.0	-9.452363E-01	-8.521978E-03	6.570704E-03	0.0
18	G	0.0	0.0	-1.102257E+00	-1.064264E-02	1.365244E-03	0.0
19	G	0.0	0.0	-6.211806E-01	-6.145253E-03	0.0	0.0
20	G	0.0	0.0	-6.708307E-02	5.696573E-04	6.503554E-03	0.0
21	G	0.0	0.0	-5.063871E-01	1.943438E-03	5.238074E-03	0.0
22	G	0.0	0.0	-6.056059E-01	3.724224E-03	1.955162E-03	0.0
23	G	0.0	0.0	-6.808949E-01	5.505011E-03	6.855594E-03	0.0
24	G	0.0	0.0	-9.945267E-01	2.682920E-03	1.004253E-02	0.0
25	G	0.0	0.0	-1.183793E+00	-1.391715E-04	1.612748E-03	0.0
26	G	0.0	0.0	-6.288243E-01	5.328830E-03	0.0	0.0
27	G	0.0	0.0	-4.934039E-02	1.681171E-03	6.503554E-03	0.0
28	G	0.0	0.0	-4.291956E-01	7.611310E-03	3.615558E-03	0.0
29	G	0.0	0.0	-4.698463E-01	1.198899E-02	-1.145460E-04	0.0
30	G	0.0	0.0	-5.023646E-01	1.636668E-02	7.047219E-03	0.0
31	G	0.0	0.0	-8.677683E-01	1.278541E-02	1.219568E-02	0.0
32	G	0.0	0.0	-1.107134E+00	9.204139E-03	2.425208E-03	0.0
33	G	0.0	0.0	-4.622178E-01	1.575992E-02	0.0	0.0
34	G	0.0	0.0	0.0	2.349676E-03	6.503554E-03	0.0
35	G	0.0	0.0	-1.987479E-01	1.118593E-02	-2.537825E-03	0.0
36	G	0.0	0.0	-3.966905E-02	1.727116E-02	-5.638149E-03	0.0
37	G	0.0	0.0	0.0	2.335638E-02	7.269983E-03	0.0
38	G	0.0	0.0	-4.380162E-01	1.924673E-02	1.684198E-02	0.0
39	G	0.0	0.0	-8.000544E-01	1.513708E-02	3.731625E-03	0.0
40	G	0.0	0.0	0.0	2.245131E-02	0.0	0.0

TABLE A-8. HEGS-20 FLOOR ANALYSIS (continued)

HEGS-20 GONDOLA
RUN 3.01, FLOOR GRID, LIMIT LOAD, 60-40 DIST., 690 PSF

SUBCASE 1

L O A D   V E C T O R

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
1	G	0.0	0.0	-2.341914E-05	0.0	0.0	0.0
2	G	0.0	0.0	-2.091412E-02	0.0	1.586106E-01	0.0
3	G	0.0	0.0	-3.455335E-02	0.0	5.758892E-05	0.0
4	G	0.0	0.0	-3.860228E-02	0.0	7.575066E-02	0.0
5	G	0.0	0.0	-1.028949E-02	0.0	0.0	0.0
6	G	0.0	0.0	-4.429737E-03	0.0	9.800157E-02	0.0
7	G	0.0	0.0	-9.664318E-01	0.0	2.591312E+00	0.0
8	G	0.0	0.0	-1.363570E+00	0.0	7.105427E-14	0.0
9	G	0.0	0.0	-1.363570E+00	0.0	-1.421085E-13	0.0
10	G	0.0	0.0	-1.363570E+00	0.0	-2.842171E-14	0.0
11	G	0.0	0.0	-2.361651E+00	0.0	1.576185E+01	0.0
12	G	0.0	0.0	-8.158924E-01	0.0	0.0	0.0
13	G	0.0	0.0	-3.083700E-03	0.0	0.0	0.0
14	G	0.0	0.0	-1.497509E+00	0.0	3.936321E+00	0.0
15	G	0.0	0.0	-2.107574E+00	0.0	8.526513E-14	0.0
16	G	0.0	0.0	-2.107574E+00	0.0	-2.273737E-13	0.0
17	G	0.0	0.0	-2.107574E+00	0.0	-5.684342E-14	0.0
18	G	0.0	0.0	-3.650239E+00	0.0	2.436200E+01	0.0
19	G	0.0	0.0	-1.261068E+00	0.0	0.0	0.0
20	G	0.0	0.0	-3.083700E-03	0.0	0.0	0.0
21	G	0.0	0.0	-1.497509E+00	0.0	3.936321E+00	0.0
22	G	0.0	0.0	-2.107574E+00	0.0	8.526513E-14	0.0
23	G	0.0	0.0	-2.107574E+00	0.0	-2.273737E-13	0.0
24	G	0.0	0.0	-2.107574E+00	0.0	-5.684342E-14	0.0
25	G	0.0	0.0	-3.650239E+00	0.0	2.436200E+01	0.0
26	G	0.0	0.0	-1.261068E+00	0.0	0.0	0.0
27	G	0.0	0.0	-3.780724E-03	0.0	0.0	0.0
28	G	0.0	0.0	-1.835999E+00	0.0	4.826067E+00	0.0
29	G	0.0	0.0	-2.583960E+00	0.0	1.136868E-13	0.0
30	G	0.0	0.0	-2.583960E+00	0.0	-2.842171E-13	0.0
31	G	0.0	0.0	-2.583960E+00	0.0	-8.526513E-14	0.0
32	G	0.0	0.0	-4.475321E+00	0.0	2.986866E+01	0.0
33	G	0.0	0.0	-1.546114E+00	0.0	0.0	0.0
34	G	0.0	0.0	-1.748893E-03	0.0	0.0	0.0
35	G	0.0	0.0	-9.167858E-01	0.0	2.401358E+00	0.0
36	G	0.0	0.0	-1.290077E+00	0.0	2.842171E-14	0.0
37	G	0.0	0.0	-1.290077E+00	0.0	-1.278977E-13	0.0
38	G	0.0	0.0	-1.290077E+00	0.0	-4.263256E-14	0.0
39	G	0.0	0.0	-2.237755E+00	0.0	1.511092E+01	0.0
40	G	0.0	0.0	-7.685273E-01	0.0	0.0	0.0

F O R C E S   O F   S I N G L E - P O I N T   C O N S T R A I N T

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
1	G	0.0	0.0	9.234271E-01	0.0	0.0	0.0
3	G	0.0	0.0	1.641999E+01	0.0	0.0	0.0
5	G	0.0	0.0	5.555001E+00	0.0	0.0	0.0
34	G	0.0	0.0	1.312539E+00	0.0	0.0	0.0
37	G	0.0	0.0	2.475498E+01	0.0	0.0	0.0
40	G	0.0	0.0	8.254945E+00	0.0	0.0	0.0

TABLE A-8. HEGS-20 FLOOR ANALYSIS (continued)

HEGS-20 GONDOLA
RUN 3.01, FLOOR GRID, LIMIT LOAD, 60-40 DIST., 690 PSF

SUBCASE 1

F O R C E S   I N   B A R   E L E M E N T S   (C B A R)

ELEMENT ID.	BEND-MOMENT END-A PLANE 1	BEND-MOMENT END-A PLANE 2	BEND-MOMENT END-B PLANE 1	BEND-MOMENT END-B PLANE 2	SHEAR PLANE 1	SHEAR PLANE 2	AXIAL FORCE	TORQUE
1	0.0	0.0	0.0	2.456961E+01	0.0	-4.195630E-01	0.0	-7.120364E-02
2	0.0	2.481928E+01	0.0	-4.805447E+01	0.0	1.244429E+00	0.0	-6.564094E-02
3	0.0	-4.801938E+01	0.0	5.594208E+01	0.0	-1.774995E+00	0.0	-1.275729E-02
4	0.0	5.601243E+01	0.0	-4.547474E-13	0.0	9.564965E-01	0.0	1.831314E-02
5	0.0	9.800157E-02	0.0	1.418441E+01	0.0	-2.405466E-01	0.0	0.0
6	0.0	1.673625E+01	0.0	6.315734E+00	0.0	3.558918E-01	0.0	-4.527362E-02
7	0.0	6.315734E+00	0.0	-4.403010E+01	0.0	1.719461E+00	0.0	-4.527362E-02
8	0.0	-4.403689E+01	0.0	1.896676E+01	0.0	-2.151764E+00	0.0	-1.990450E-02
9	0.0	1.896676E+01	0.0	4.204510E+01	0.0	-7.881945E-01	0.0	-1.990950E-02
10	0.0	5.778875E+01	0.0	-6.821210E-13	0.0	9.866613E-01	0.0	2.403673E-02
11	0.0	6.033268E-14	0.0	1.213899E+01	0.0	-2.072914E-01	0.0	-2.604316E-02
12	0.0	1.601878E+01	0.0	1.383658E+01	0.0	7.452845E-02	0.0	-1.327905E-02
13	0.0	1.383658E+01	0.0	-5.005539E+01	0.0	2.182103E+00	0.0	-1.327905E-02
14	0.0	-5.006340E+01	0.0	2.662762E+01	0.0	-2.619229E+00	0.0	-2.897073E-02
15	0.0	2.662762E+01	0.0	4.160887E+01	0.0	-5.116546E-01	0.0	-2.897073E-02
16	0.0	6.597413E+01	0.0	-4.547474E-13	0.0	1.126415E+00	0.0	3.071458E-02
17	0.0	6.101170E-14	0.0	1.559355E+01	0.0	-2.662833E-01	0.0	9.383747E-03
18	0.0	1.949162E+01	0.0	1.159792E+01	0.0	2.695933E-01	0.0	2.432768E-02
19	0.0	1.159792E+01	0.0	-5.800555E+01	0.0	2.377168E+00	0.0	2.432768E-02
20	0.0	-5.802067E+01	0.0	2.784002E+01	0.0	-2.932401E+00	0.0	-3.855316E-02
21	0.0	2.784002E+01	0.0	5.199094E+01	0.0	-8.248265E-01	0.0	-3.855316E-02
22	0.0	7.636799E+01	0.0	-1.364242E-12	0.0	1.303875E+00	0.0	3.734336E-02
23	0.0	4.487482E-14	0.0	1.977721E+01	0.0	-3.377257E-01	0.0	4.050641E-02
24	0.0	2.453446E+01	0.0	1.079004E+01	0.0	4.694133E-01	0.0	5.980442E-02
25	0.0	1.079004E+01	0.0	-7.861274E+01	0.0	3.053373E+00	0.0	5.980442E-02
26	0.0	-7.861378E+01	0.0	2.985733E+01	0.0	-3.704614E+00	0.0	-4.892444E-02
27	0.0	2.985733E+01	0.0	6.267009E+01	0.0	-1.120654E+00	0.0	-4.892444E-02
28	0.0	9.254089E+01	0.0	-9.094947E-13	0.0	1.580005E+00	0.0	4.477228E-02
29	0.0	0.0	0.0	4.382663E+01	0.0	-7.484055E-01	0.0	6.001539E-02
30	0.0	4.634002E+01	0.0	-1.519125E+01	0.0	2.101478E+00	0.0	8.313152E-02
31	0.0	-1.519125E+01	0.0	-1.144960E+02	0.0	3.391555E+00	0.0	8.313152E-02
32	0.0	-1.145000E+02	0.0	1.833078E+01	0.0	-4.536571E+00	0.0	-5.614281E-02
33	0.0	1.833078E+01	0.0	1.133881E+02	0.0	-3.246494E+00	0.0	-5.614281E-02
34	0.0	1.284753E+02	0.0	0.0	0.0	2.193534E+00	0.0	4.495211E-02
35	0.0	7.120369E-02	0.0	1.114058E+01	0.0	-5.038406E-01	0.0	0.0
36	0.0	1.114058E+01	0.0	1.502872E+01	0.0	-2.588643E-01	0.0	-3.019807E-14
37	0.0	1.505477E+01	0.0	1.578307E+01	0.0	-4.848914E-02	0.0	-1.665175E-14
38	0.0	1.577369E+01	0.0	1.245610E+01	0.0	2.208779E-01	0.0	-1.154632E-14
39	0.0	1.241560E+01	0.0	6.001539E-02	0.0	5.623843E-01	0.0	-4.440892E-15
40	0.0	-5.288365E-02	0.0	2.935984E+02	0.0	-1.336601E+01	0.0	3.503524E-02
41	0.0	2.935730E+02	0.0	4.157038E+02	0.0	-8.131215E+00	0.0	2.824165E-02
42	0.0	4.157195E+02	0.0	4.340786E+02	0.0	-1.222309E+00	0.0	2.022902E-02
43	0.0	4.341415E+02	0.0	3.410951E+02	0.0	6.194834E+00	0.0	5.103212E-03
44	0.0	3.412038E+02	0.0	-1.392743E-01	0.0	1.553678E+01	0.0	4.055774E-03
45	0.0	1.831314E-02	0.0	1.008214E+02	0.0	-4.588215E+00	0.0	0.0
46	0.0	1.008454E+02	0.0	1.426861E+02	0.0	-2.785661E+00	0.0	0.0
47	0.0	1.427168E+02	0.0	1.486974E+02	0.0	-3.981781E-01	0.0	0.0
48	0.0	1.487348E+02	0.0	1.161899E+02	0.0	2.166765E+00	0.0	0.0
49	0.0	1.162347E+02	0.0	-4.995211E-02	0.0	5.292884E+00	0.0	0.0
50	0.0	-5.562733E-03	0.0	3.609285E+01	0.0	-1.643076E+00	0.0	9.105794E-02

TABLE A-8. HEGS-20 FLOOR ANALYSIS (continued)

HEGS-20 GONDOLA
RUN 3.01, FLOOR GRID, LIMIT LOAD, 60-40 DIST., 690 PSF

SUBCASE 1

FORCES IN BAR ELEMENTS (CBAR)

ELEMENT ID.	BEND-MOMENT END-A PLANE 1	BEND-MOMENT END-A PLANE 2	BEND-MOMENT END-B PLANE 1	BEND-MOMENT END-B PLANE 2	SHEAR PLANE 1	SHEAR PLANE 2	AXIAL FORCE	TORQUE
51	0.0	3.613813E+01	0.0	5.525985E+01	0.0	-1.273084E+00	0.0	5.157933E-02
52	0.0	5.524709E+01	0.0	5.610916E+01	0.0	-5.739491E-02	0.0	-4.952570E-03
53	0.0	5.609422E+01	0.0	4.251257E+01	0.0	9.042377E-01	0.0	-4.320948E-02
54	0.0	4.249327E+01	0.0	2.311613E-02	0.0	1.933098E+00	0.0	-1.120325E-01
55	0.0	-3.107288E-02	0.0	5.913171E+01	0.0	-2.692889E+00	0.0	-5.385998E-03
56	0.0	5.908776E+01	0.0	9.072130E+01	0.0	-2.106094E+00	0.0	3.329067E-03
57	0.0	9.066161E+01	0.0	9.207237E+01	0.0	-9.392500E-02	0.0	6.591317E-03
58	0.0	9.199647E+01	0.0	7.055374E+01	0.0	1.427612E+00	0.0	2.163674E-02
59	0.0	7.046004E+01	0.0	1.060949E-01	0.0	3.202273E+00	0.0	2.378548E-02

TABLE A-8. HEGS-20 FLOOR ANALYSIS (continued)

HEGS-20 GONDOLA
RUN 3.01, FLOOR GRID, LIMIT LOAD, 60-40 DIST., 690 PSF

SUBCASE 1

S T R E S S E S   I N   B A R   E L E M E N T S   (C B A R)

ELEMENT ID.	SA1 SB1	SA2 SB2	SA3 SB3	SA4 SB4	AXIAL STRESS	SA-MAX SB-MAX	SA-MIN SB-MIN	M.S.-T M.S.-C
1	0.0 -4.450777E+00	0.0 4.560223E+00	0.0 0.0	0.0 0.0	0.0	0.0 4.560223E+00	0.0 -4.450777E+00	4.7E+00 5.1E+00
2	-4.496005E+00 8.705052E+00	4.606562E+00 -8.919111E+00	0.0 0.0	0.0 0.0	0.0	4.606562E+00 8.705052E+00	-4.496005E+00 -8.919111E+00	2.0E+00 2.0E+00
3	8.698695E+00 -1.013389E+01	-8.912598E+00 1.038308E+01	0.0 0.0	0.0 0.0	0.0	8.698695E+00 1.038308E+01	-8.912598E+00 -1.013389E+01	1.5E+00 1.7E+00
4	-1.014663E+01 8.237734E-14	1.039614E+01 -8.440301E-14	0.0 0.0	0.0 0.0	0.0	1.039614E+01 8.237734E-14	-1.014663E+01 -8.440301E-14	1.5E+00 1.7E+00
5	-1.504097E-02 -2.176979E+00	2.309811E-02 3.343142E+00	0.0 0.0	0.0 0.0	0.0	2.309811E-02 3.343142E+00	-1.504097E-02 -2.176979E+00	6.8E+00 1.1E+01
6	-2.568626E+00 -9.693189E-01	3.944586E+00 1.488563E+00	0.0 0.0	0.0 0.0	0.0	3.944586E+00 1.488563E+00	-2.568626E+00 -9.693189E-01	5.6E+00 9.5E+00
7	-9.693189E-01 6.757601E+00	1.488563E+00 -1.037751E+01	0.0 0.0	0.0 0.0	0.0	1.488563E+00 6.757601E+00	-9.693189E-01 -1.037751E+01	2.8E+00 1.6E+00
8	6.758643E+00 -2.910959E+00	-1.037911E+01 4.470300E+00	0.0 0.0	0.0 0.0	0.0	6.758643E+00 4.470300E+00	-1.037911E+01 -2.910959E+00	2.8E+00 1.6E+00
9	-2.910959E+00 -6.452950E+00	4.470300E+00 9.909662E+00	0.0 0.0	0.0 0.0	0.0	4.470300E+00 9.909662E+00	-2.910959E+00 -6.452950E+00	1.6E+00 3.2E+00
10	-8.869236E+00 1.046898E-13	1.362030E+01 -1.607700E-13	0.0 0.0	0.0 0.0	0.0	1.362030E+01 1.046898E-13	-8.869236E+00 -1.607700E-13	9.1E-01 2.0E+00
11	-9.259671E-15 -1.863053E+00	1.421989E-14 2.861053E+00	0.0 0.0	0.0 0.0	0.0	1.421989E-14 2.861053E+00	-9.259671E-15 -1.863053E+00	8.1E+00 1.3E+01
12	-2.458511E+00 -2.123595E+00	3.775485E+00 3.261161E+00	0.0 0.0	0.0 0.0	0.0	3.775485E+00 3.261161E+00	-2.458511E+00 -2.123595E+00	5.9E+00 1.0E+01
13	-2.123595E+00 7.682344E+00	3.261161E+00 -1.179762E+01	0.0 0.0	0.0 0.0	0.0	3.261161E+00 7.682344E+00	-2.123595E+00 -1.179762E+01	2.4E+00 1.3E+00
14	7.683574E+00 -4.086724E+00	-1.179951E+01 6.275898E+00	0.0 0.0	0.0 0.0	0.0	7.683574E+00 6.275898E+00	-1.179951E+01 -4.086724E+00	2.4E+00 1.3E+00
15	-4.086724E+00 -6.385999E+00	6.275898E+00 9.806847E+00	0.0 0.0	0.0 0.0	0.0	6.275898E+00 9.806847E+00	-4.086724E+00 -6.385999E+00	1.7E+00 3.2E+00
16	-1.012550E+01 6.979319E-14	1.554953E+01 -1.071800E-13	0.0 0.0	0.0 0.0	0.0	1.554953E+01 6.979319E-14	-1.012550E+01 -1.071800E-13	6.7E-01 1.7E+00

TABLE A-8. HEGS-20 FLOOR ANALYSIS (continued)

HEGS-20 GONDOLA
RUN 3.01, FLOOR GRID, LIMIT LOAD, 60-40 DIST., 690 PSF

SUBCASE 1

STRESSES IN BAR ELEMENTS (CBAR)

ELEMENT ID.	SA1 SB1	SA2 SB2	SA3 SB3	SA4 SB4	AXIAL STRESS	SA-MAX SB-MAX	SA-MIN SB-MIN	M.S.-T M.S.-C
17	-9.363884E-15 -2.393249E+00	1.437992E-14 3.675264E+00	0.0 0.0	0.0 0.0	0.0	1.437992E-14 3.675264E+00	-9.363884E-15 -2.393249E+00	6.1E+00 1.0E+01
18	-2.991512E+00 -1.780013E+00	4.594003E+00 2.733529E+00	0.0 0.0	0.0 0.0	0.0	4.594003E+00 2.733529E+00	-2.991512E+00 -1.780013E+00	4.7E+00 8.0E+00
19	-1.780013E+00 8.902509E+00	2.733529E+00 -1.367140E+01	0.0 0.0	0.0 0.0	0.0	2.733529E+00 8.902509E+00	-1.780013E+00 -1.367140E+01	1.9E+00 9.7E-01
20	8.904831E+00 -4.272800E+00	-1.367496E+01 6.561650E+00	0.0 0.0	0.0 0.0	0.0	8.904831E+00 6.561650E+00	-1.367496E+01 -4.272800E+00	1.9E+00 9.7E-01
21	-4.272800E+00 -7.979407E+00	6.561650E+00 1.225381E+01	0.0 0.0	0.0 0.0	0.0	6.561650E+00 1.225381E+01	-4.272800E+00 -7.979407E+00	1.1E+00 2.4E+00
22	-1.172072E+01 2.093796E-13	1.799927E+01 -3.215399E-13	0.0 0.0	0.0 0.0	0.0	1.799927E+01 2.093796E-13	-1.172072E+01 -3.215399E-13	4.4E-01 1.3E+00
23	-6.887247E-15 -3.035345E+00	1.057660E-14 4.661316E+00	0.0 0.0	0.0 0.0	0.0	1.057660E-14 4.661316E+00	-6.887247E-15 -3.035345E+00	4.6E+00 7.9E+00
24	-3.765472E+00 -1.656021E+00	5.782557E+00 2.543117E+00	0.0 0.0	0.0 0.0	0.0	5.782557E+00 2.543117E+00	-3.765472E+00 -1.656021E+00	3.5E+00 6.2E+00
25	-1.656021E+00 1.206524E+01	2.543117E+00 -1.852833E+01	0.0 0.0	0.0 0.0	0.0	2.543117E+00 1.206524E+01	-1.656021E+00 -1.852833E+01	1.2E+00 4.6E-01
26	1.206540E+01 -4.582409E+00	-1.852858E+01 7.037110E+00	0.0 0.0	0.0 0.0	0.0	1.206540E+01 7.037110E+00	-1.852858E+01 -4.582409E+00	1.2E+00 4.6E-01
27	-4.582409E+00 -9.618408E+00	7.037110E+00 1.477079E+01	0.0 0.0	0.0 0.0	0.0	7.037110E+00 1.477079E+01	-4.582409E+00 -9.618408E+00	7.6E-01 1.8E+00
28	-1.420289E+01 1.395864E-13	2.181108E+01 -2.143599E-13	0.0 0.0	0.0 0.0	0.0	2.181108E+01 1.395864E-13	-1.420289E+01 -2.143599E-13	1.9E-01 9.0E-01
29	0.0 -7.939180E+00	0.0 8.134406E+00	0.0 0.0	0.0 0.0	0.0	0.0 8.134406E+00	0.0 -7.939180E+00	2.2E+00 2.4E+00
30	-8.394480E+00 2.751891E+00	8.600901E+00 -2.819560E+00	0.0 0.0	0.0 0.0	0.0	8.600901E+00 2.751891E+00	-8.394480E+00 -2.819560E+00	2.0E+00 2.2E+00
31	2.751891E+00 2.074091E+01	-2.819560E+00 -2.125093E+01	0.0 0.0	0.0 0.0	0.0	2.751891E+00 2.074091E+01	-2.819560E+00 -2.125093E+01	2.5E-01 2.7E-01
32	2.074164E+01 -3.320615E+00	-2.125168E+01 3.402269E+00	0.0 0.0	0.0 0.0	0.0	2.074164E+01 3.402269E+00	-2.125168E+01 -3.320615E+00	2.5E-01 2.7E-01

TABLE A-8. HEGS-20 FLOOR ANALYSIS (continued)

HEGS-20 GONDOLA
RUN 3.01. FLOOR GRID. LIMIT LOAD. 60-40 DIST., 690 PSF

SUBCASE 1

STRESSES IN BAR ELEMENTS (CBAR)

ELEMENT ID.	SA1 SB1	SA2 SB2	SA3 SB3	SA4 SB4	AXIAL STRESS	SA-MAX SB-MAX	SA-MIN SB-MIN	M.S.-T M.S.-C
33	-3.320615E+00 -2.054022E+01	3.402269E+00 2.104531E+01	0.0 0.0	0.0 0.0	0.0	3.402269E+00 2.104531E+01	-3.320615E+00 -2.054022E+01	2.4E-01 3.1E-01
34	-2.327326E+01 0.0	2.384555E+01 0.0	0.0 0.0	0.0 0.0	0.0	2.384555E+01 0.0	-2.327326E+01 0.0	9.0E-02 1.6E-01
35	-9.830300E-03 -1.538056E+00	1.031172E-02 1.613380E+00	0.0 0.0	0.0 0.0	0.0	1.031172E-02 1.613380E+00	-9.830300E-03 -1.538056E+00	1.5E+01 1.7E+01
36	-1.538056E+00 -2.074849E+00	1.613380E+00 2.176461E+00	0.0 0.0	0.0 0.0	0.0	1.613380E+00 2.176461E+00	-1.538056E+00 -2.074849E+00	1.1E+01 1.2E+01
37	-2.078444E+00 -2.178994E+00	2.180232E+00 2.285706E+00	0.0 0.0	0.0 0.0	0.0	2.180232E+00 2.285706E+00	-2.078444E+00 -2.178994E+00	1.0E+01 1.1E+01
38	-2.177698E+00 -1.719676E+00	2.284347E+00 1.803894E+00	0.0 0.0	0.0 0.0	0.0	2.284347E+00 1.803894E+00	-2.177698E+00 -1.719676E+00	1.0E+01 1.1E+01
39	-1.714084E+00 -8.285658E-03	1.798028E+00 8.691432E-03	0.0 0.0	0.0 0.0	0.0	1.798028E+00 8.691432E-03	-1.714084E+00 -8.285658E-03	1.3E+01 1.5E+01
40	2.754998E-03 -1.529514E+01	-3.016646E-03 1.674775E+01	0.0 0.0	0.0 0.0	0.0	2.754998E-03 1.674775E+01	-3.016646E-03 -1.529514E+01	5.5E-01 7.7E-01
41	-1.529382E+01 -2.165628E+01	1.674631E+01 2.371303E+01	0.0 0.0	0.0 0.0	0.0	1.674631E+01 2.371303E+01	-1.529382E+01 -2.165628E+01	9.6E-02 2.5E-01
42	-2.165710E+01 -2.261353E+01	2.371392E+01 2.476118E+01	0.0 0.0	0.0 0.0	0.0	2.371392E+01 2.476118E+01	-2.165710E+01 -2.261353E+01	5.0E-02 1.9E-01
43	-2.261680E+01 -1.776951E+01	2.476477E+01 1.945711E+01	0.0 0.0	0.0 0.0	0.0	2.476477E+01 1.945711E+01	-2.261680E+01 -1.776951E+01	5.0E-02 1.9E-01
44	-1.777517E+01 7.255560E-03	1.946331E+01 -7.944636E-03	0.0 0.0	0.0 0.0	0.0	1.946331E+01 7.255560E-03	-1.777517E+01 -7.944636E-03	3.4E-01 5.2E-01
45	-2.528292E-03 -1.391929E+01	2.652110E-03 1.460096E+01	0.0 0.0	0.0 0.0	0.0	2.652110E-03 1.460096E+01	-2.528292E-03 -1.391929E+01	7.8E-01 9.4E-01
46	-1.392261E+01 -1.969908E+01	1.460444E+01 2.066380E+01	0.0 0.0	0.0 0.0	0.0	1.460444E+01 2.066380E+01	-1.392261E+01 -1.969908E+01	2.6E-01 3.7E-01
47	-1.970332E+01 -2.052900E+01	2.066825E+01 2.153437E+01	0.0 0.0	0.0 0.0	0.0	2.066825E+01 2.153437E+01	-1.970332E+01 -2.052900E+01	2.1E-01 3.2E-01
48	-2.053415E+01 -1.604105E+01	2.153978E+01 1.682663E+01	0.0 0.0	0.0 0.0	0.0	2.153978E+01 1.682663E+01	-2.053415E+01 -1.604105E+01	2.1E-01 3.1E-01

TABLE A-8. HEGS-20 FLOOR ANALYSIS (continued)

HEGS-20 GONDOLA
RUN 3.01, FLOOR GRID, LIMIT LOAD, 60-40 DIST., 690 PSF

SUBCASE 1

S T R E S S E S   I N   B A R   E L E M E N T S   (C B A R)

ELEMENT ID.	SA1 SB1	SA2 SB2	SA3 SB3	SA4 SB4	AXIAL STRESS	SA-MAX SB-MAX	SA-MIN SB-MIN	M.S.-T M.S.-C
49	-1.604723E+01 6.896333E-03	1.683312E+01 -7.234068E-03	0.0 0.0	0.0 0.0	0.0	1.683312E+01 6.896333E-03	-1.604723E+01 -7.234068E-03	5.4E-01 6.8E-01
50	9.652756E-04 -6.263028E+00	-1.331903E-03 8.641830E+00	0.0 0.0	0.0 0.0	0.0	9.652756E-04 8.641830E+00	-1.331903E-03 -6.263028E+00	2.0E+00 3.3E+00
51	-6.270884E+00 -9.588990E+00	8.652670E+00 1.323105E+01	0.0 0.0	0.0 0.0	0.0	8.652670E+00 1.323105E+01	-6.270884E+00 -9.588990E+00	9.7E-01 1.8E+00
52	-9.586775E+00 -9.736366E+00	1.322799E+01 1.343440E+01	0.0 0.0	0.0 0.0	0.0	1.322799E+01 1.343440E+01	-9.586775E+00 -9.736366E+00	9.4E-01 1.8E+00
53	-9.733773E+00 -7.377012E+00	1.343082E+01 1.017892E+01	0.0 0.0	0.0 0.0	0.0	1.343082E+01 1.017892E+01	-9.733773E+00 -7.377012E+00	9.4E-01 1.8E+00
54	-7.373663E+00 -4.011237E-03	1.017430E+01 5.534770E-03	0.0 0.0	0.0 0.0	0.0	1.017430E+01 5.534770E-03	-7.373663E+00 -4.011237E-03	1.6E+00 2.7E+00
55	5.391935E-03 -1.026086E+01	-7.439881E-03 1.415810E+01	0.0 0.0	0.0 0.0	0.0	5.391935E-03 1.415810E+01	-7.439881E-03 -1.026086E+01	8.4E-01 1.6E+00
56	-1.025323E+01 -1.574245E+01	1.414758E+01 2.172170E+01	0.0 0.0	0.0 0.0	0.0	1.414758E+01 2.172170E+01	-1.025323E+01 -1.574245E+01	2.0E-01 7.2E-01
57	-1.573210E+01 -1.597690E+01	2.170740E+01 2.204519E+01	0.0 0.0	0.0 0.0	0.0	2.170740E+01 2.204519E+01	-1.573210E+01 -1.597690E+01	1.8E-01 6.9E-01
58	-1.596373E+01 -1.224287E+01	2.202701E+01 1.689291E+01	0.0 0.0	0.0 0.0	0.0	2.202701E+01 1.689291E+01	-1.596373E+01 -1.224287E+01	1.8E-01 6.9E-01
59	-1.222661E+01 -1.841017E-02	1.687048E+01 2.540265E-02	0.0 0.0	0.0 0.0	0.0	1.687048E+01 2.540265E-02	-1.222661E+01 -1.841017E-02	5.4E-01 1.2E+00

COLUMNS

Corner Columns

Tubing

Material: 6061-T6 aluminum

Limit Load: 9.3 kips; - 16.2 kips

Size: 3-3/4 in. diameter x .125 in. thick x 85.6 in. long

$$A = \pi D_m t = \pi(3.625)(.125) = 1.424 \text{ in.}^2$$

$$I = \frac{\pi}{64}[D_o{}^4 - D_i{}^4] = \frac{\pi}{64}[(3.75)^4 - (3.50)^4] = 2.341 \text{ in.}^4$$

Buckling - Center of Tube

From Figure 1.6.3.2, Reference 6:

$$B = \frac{L'/\rho}{\sqrt{E/F_{co}}} \qquad \text{where } L' = \frac{L}{\sqrt{C}}$$

For simply supported ends, C = 1

$$L' = L$$

$$\rho = \sqrt{I/A} = \sqrt{\frac{2.341}{1.424}} = 1.282 \text{ in.}$$

$$B = \frac{85.6/1.282}{\sqrt{\frac{10,000}{35.0}}} = 1.251$$

$$R_a = 1 - .385\ B = 1 - .385\ (1.251) = .518$$

$$F_c = R_a\ F_{co} = .518\ (35.0) = 18.14 \text{ ksi}$$

$$\text{Ult. Compressive Stress, } f_u = \frac{1.5\ P_y}{A} = \frac{1.5\ (-\ 16.2)}{1.424} = 17.06 \text{ ksi}$$

$$MS_u = \frac{18.14}{17.06} - 1 = \underline{\underline{.06}}$$

Compression Yield Stress at Tube Ends (Heat-affected Zone)

Limit Compression Load, P_y = 16.2 kips

$$f_{cy} = \frac{P_y}{A} = \frac{-16.2}{1.424} = 11.38 \text{ ksi}$$

F_{cy} = 20.0 ksi

$$MS_{cy} = \frac{20.0}{11.38} - 1 = \underline{\underline{.76}}$$

Compression Ultimate Stress at Tube Ends (Heat-affected Zone)

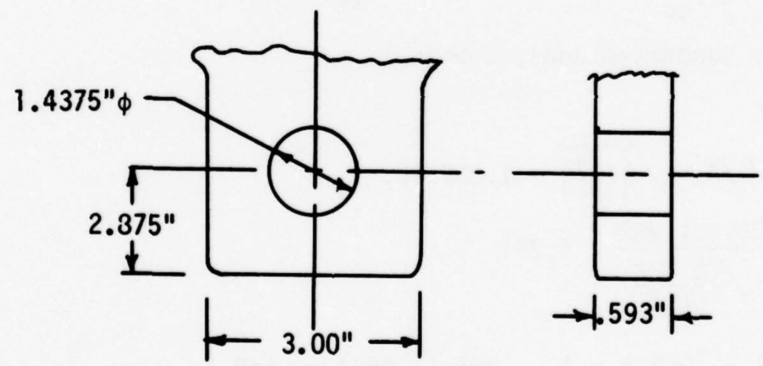
Ultimate Compression Load, $P_u = 1.5\ P_y = 1.5\ (16.2) = 24.3$ kips

$$f_{cu} = \frac{P_u}{A} = \frac{24.3}{1.424} = 17.06 \text{ ksi}$$

F_{cu} = 24.0 ksi

$$MS_{cu} = \frac{24.0}{17.06} - 1 = \underline{\underline{.41}}$$

End Lugs



Material: 6061-T6 aluminum forging

Limit Load: 9.3 kips; - 16.2 kips

Shearout

$A_s = 2\ (2.156)(.593) = 2.557\ \text{in.}^2$

Yield Shear Stress

$$f_{sy} = \frac{P_y}{A} = \frac{9.3}{2.557} = 3.64 \text{ ksi}$$

$$F_{sy} = 20.0 \text{ ksi}$$

$$MS_{sy} = \frac{20.0}{3.64} - 1 = \underline{\underline{4.49}}$$

Ultimate Shear Stress

$$f_{su} = 1.5\ f_{sy} = 1.5\ (3.64) = 5.46 \text{ ksi}$$

$$F_{su} = 25.0 \text{ ksi}$$

$$MS_{su} = \frac{25.0}{5.46} - 1 = \underline{\underline{3.58}}$$

Tensile Stress

$$A_t = (3.0 - 1.4375)\ .593 = .926 \text{ in.}^2$$

Yield Stress

$$f_{ty} = \frac{P_y}{A_t} = \frac{9.3}{.926} = 10.04 \text{ ksi}$$

$$F_{ty} = 35.0 \text{ ksi}$$

$$MS_{ty} = \frac{35.0}{10.04} - 1 = \underline{\underline{2.49}}$$

Ultimate Stress

$$f_{tu} = 1.5\ f_{ty} = 1.5\ (10.04) = 15.06 \text{ ksi}$$

$$f_{tu} = 1.5\ (10.04) = 15.06 \text{ ksi}$$

$$F_{tu} = 38.0 \text{ ksi}$$

$$MS_{tu} = \frac{38.0}{15.06} - 1 = \underline{\underline{1.52}}$$

Bearing Stress

$$A_{br} = 1.4375\ (.593) = .852 \text{ in.}^2$$

Yield Stress

Limit Load, $P_y = -\ 16.2$ ksi

$$f_{bry} = \frac{P_y}{A_{br}} = \frac{16.2}{.852} = 19.01 \text{ ksi}$$

$$F_{bry} = 61 \text{ ksi}$$

$$MS_{bry} = \frac{61.0}{19.01} - 1 = \underline{\underline{2.21}}$$

Ultimate Stress

$f_{bru} = 1.5\ f_{bry} = 1.5\ (19.01) = 28.52$ ksi

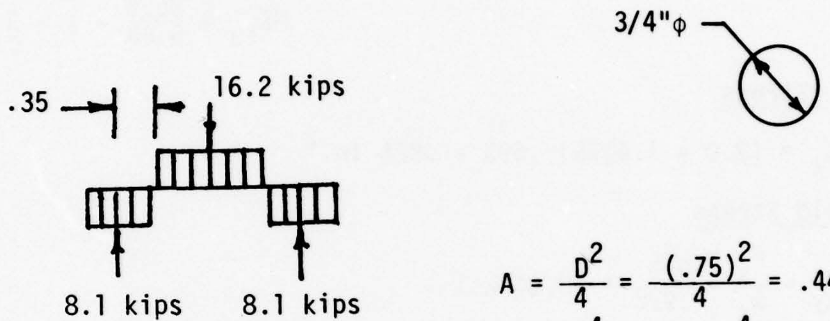
$F_{bru} = 76.0$ ksi

$$MS_{bru} = \frac{76.0}{28.52} - 1 = \underline{\underline{1.66}}$$

Column Attachment Bolt

Material: Alloy Steel, $F_{tu} = 125$ ksi

Limit Load: 9.3 kips, - 16.2 kips



$$A = \frac{D^2}{4} = \frac{(.75)^2}{4} = .442\ \text{in.}^2$$

$$I = \frac{D^4}{64} = \frac{(.75)^4}{64} = .0155\ \text{in.}^4$$

Bending Yield Stress

$M = 8.1\ (.35) = 2.835$ kip-in.

$$f_{by} = \frac{Mc}{I} = \frac{2.835\ (.375)}{.0155} = 68.59\ \text{ksi}$$

$F_{by} = 103.0$ ksi

$$MS_{by} = \frac{103.0}{68.59} - 1 = \underline{\underline{.50}}$$

Bending Ultimate Stress

$f_{bu} = 1.5\ f_{by} = 1.5\ (68.59) = 102.88$ ksi

$F_{bu} = 125.0$ ksi

$$MS_{bu} = \frac{125.0}{102.88} - 1 = \underline{\underline{.21}}$$

Ultimate Shear Stress

$$A_s = 2\,(.442) = .884 \text{ in.}^2$$

$$f_{su} = \frac{P_{su}}{A_s} = \frac{1.5\,(16.2)}{.884} = 27.49 \text{ ksi}$$

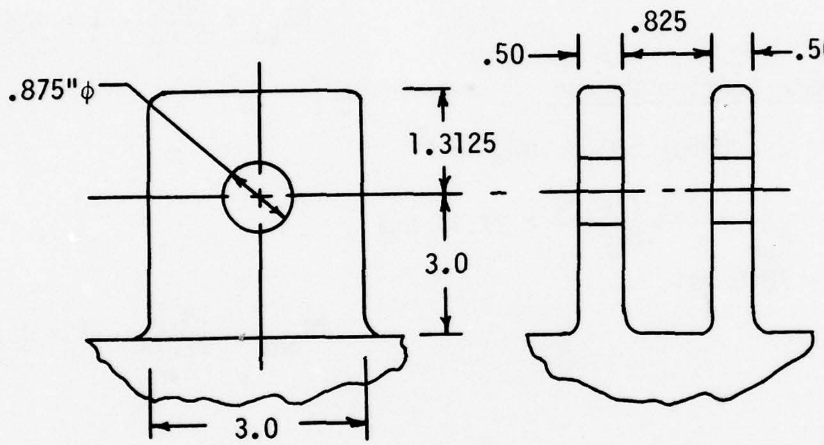
$$F_{su} = 75.0 \text{ ksi}$$

$$MS_{su} = \frac{75.0}{27.49} - 1 = \underline{\underline{1.73}}$$

Column Attachment Clevis on Corner Fittings

Material: 6066-T6 aluminum forging

Limit Load: 9.3 kips, - 16.2 kips



Shearout

$$A_s = (1.3125 - .4375)(4)(.5) = 1.75 \text{ in.}^2$$

Shear Yield Stress

$$f_{sy} = \frac{P_y}{A_s} = \frac{9.3}{1.75} = 5.31 \text{ ksi}$$

$$F_{sy} = 27.0 \text{ ksi}$$

$$MS_{sy} = \frac{27.0}{5.31} - 1 = \underline{\underline{4.08}}$$

Shear Ultimate Stress

$f_{su} = 1.5\ f_{sy} = 1.5\ (5.31) = 7.96$ ksi

$F_{su} = 34.0$ ksi

$$MS_{su} = \frac{34.0}{7.96} - 1 = \underline{\underline{3.27}}$$

Ultimate Tensile Stress

$A_t = (3.0 - .875)(2)(.50) = 2.125$ in.^{2}

$f_{tu} = \frac{P_u}{A_t} = \frac{1.5\ (9.3)}{2.125} = 6.56$ ksi

$F_{tu} = 50.0$ ksi

$$MS_{tu} = \frac{50.0}{6.56} - 1 = \underline{\underline{6.62}}$$

Ultimate Bearing Stress

$A_{br} = 2\ (.875)(.50) = .875$ in.^{2}

$f_{bru} = \frac{P_u}{A_{br}} = \frac{1.5\ (16.2)}{.875} = 27.77$ ksi

$F_{bru} = 78.0$ ksi

$$MS_{bru} = \frac{78.0}{27.77} - 1 = \underline{\underline{1.81}}$$

CENTER COLUMNS

Tubing

Material: 6061-T6 aluminum

Limit Load: - 6.2 kips

Size: 3 in. diam x .083 in. thick x 85.6 in. long

$A = \pi D_m t = \pi(2.917)(.083) = .761$ in.^{2}

$I = \frac{\pi}{64}\ [D_o^{\ 4} - D_i^{\ 4}] = \frac{\pi}{64}\ [(3.0)^4 - (2.834)^4] = .810$ in.^{4}

$\rho = \sqrt{I/A} = \sqrt{\frac{.810}{.761}} = 1.032$ in.

From Figure 1.6.3.2, Reference 6:

$$B = \frac{L/\rho}{\pi\sqrt{E/F_{co}}} = \frac{85.6/1.032}{\pi\sqrt{\frac{10,000}{35.0}}} = 1.554$$

$$R_a = 1 - .385\ B = 1 - .385\ (1.554) = .402$$

$$F_c = R_a\ F_{co} = .402\ (35.0) = 14.07 \text{ ksi}$$

$$f_{cu} = \frac{1.5\ P_y}{A} = \frac{1.5\ (6.2)}{.761} = 12.22 \text{ ksi}$$

$$MS_{cu} = \frac{14.07}{12.22} - 1 = \underline{\underline{.15}}$$

Compressive Yield Stress at Tube Ends (Heat-affected Zone)

Limit Compression Load, $P_y = -\ 6.2$ kips

$$f_{cy} = \frac{P_y}{A} = \frac{-\ 6.2}{.761} = 8.15 \text{ ksi}$$

$$F_{cy} = 20.0 \text{ ksi}$$

$$MS_{cy} = \frac{20.0}{8.15} - 1 = \underline{\underline{1.45}}$$

Compressive Ultimate Stress at Tube Ends (Heat-affected Zone)

Ultimate Compression Load, $P_u \approx 1.5\ P_y = 1.5\ (-\ 6.2) = -\ 9.3$ kips

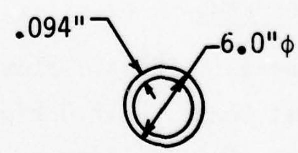
$$f_{cu} = \frac{P_u}{A} = \frac{9.3}{.761} = 12.22 \text{ ksi}$$

$$F_{cu} = 24.0 \text{ ksi}$$

$$MS_{cu} = \frac{24.0}{12.22} - 1 = \underline{\underline{.96}}$$

UPPER STRUCTURE

Upper Sides



Material: 6061-T6 aluminum

Limit Load: - 22.1 kips

Size: 6.0 in. diam x .094 in. thick x 112.4 in. long

$$A = \pi D_m t = \pi(5.906)(.094) = 1.744 \text{ in.}^2$$

$$I = \frac{\pi}{64}\left[D_o^4 - D_i^4\right] = \frac{\pi}{64}\left[(6.0)^4 - (5.812)^4\right] = 7.606 \text{ in.}^4$$

$$\rho = \sqrt{I/A} = \sqrt{\frac{7.606}{1.744}} = 2.088 \text{ in.}$$

Buckling - Center of Tube

Assume ends are simply supported. From Figure 1.6.3.2, Reference 6:

$$B = \frac{L'/\rho}{\pi\sqrt{E/F_{co}}} = \frac{112.4/2.088}{\pi\sqrt{\frac{10,000}{35.0}}} = 1.009$$

$$R_a = 1 - .385\ B = 1 - .385\ (1.009) = .612$$

$$F_c = R_a\ F_{co} = .612\ (35.0) = 21.42 \text{ ksi}$$

Ult. Compressive Stress, $f_u = \frac{1.5\ P_y}{A} = \frac{1.5\ (-\ 22.1)}{1.744} = -\ 19.01$ ksi

$$MS_u = \frac{21.42}{19.01} - 1 = \underline{\underline{.13}}$$

Compression Yield Stress at Tube Ends (Heat-affected Zone)

Limit Compression Load, $P_y = -\ 22.1$ kips

$$f_{cy} = \frac{P_y}{A} = \frac{-\ 22.1}{1.744} = 12.67 \text{ ksi}$$

$$F_{cy} = 24.0 \text{ ksi}$$

$$MS_{cy} = \frac{24.0}{12.67} - 1 = \underline{\underline{.89}}$$

Compression Ultimate Stress at Tube Ends (Heat-affected Zone)

$$f_{cu} = 1.5\ f_{cy} = 1.5\ (12.67) = 19.01 \text{ ksi}$$

$$F_{cu} = 24.0 \text{ ksi}$$

$$MS_{cu} = \frac{24.0}{19.01} - 1 = \underline{\underline{.26}}$$

Upper Ends

Material: 6061-T6 aluminum tubing

Limit Load: - 17.0 kips

Size: 6.0 in. diam x .094 in. thick x 82.5 in. long

$A = 1.744$ in.^{2} $\quad I = 7.606$ in.^{4} $\quad \rho = 2.088$ in.

Buckling - Center of Tube

From Figure 1.6.3.2, Reference 6:

$$B = \frac{L'/\rho}{\pi\sqrt{E/F_{co}}} = \frac{82.5/2.088}{\pi\sqrt{\frac{10,100}{35.0}}} = .740$$

$$R_a = 1 - .385\ B = 1 - .385\ (.740) = .715$$

$$F_c = R_a\ F_{co} = .715\ (35.0) = 25.03\ \text{ksi}$$

Ult. Compressive Stress, $f_u = \frac{1.5\ P_y}{A} = \frac{1.5\ (-\ 17.0)}{1.744} = 14.62$ ksi

$$MS_u = \frac{25.03}{14.62} - 1 = \underline{\underline{.71}}$$

Compression Yield Stress at Tube Ends (Heat-affected Zone)

Limit Compression Load, $P_y = -\ 17.0$ kips

$$f_{cy} = \frac{P_y}{A} = \frac{-\ 17.0}{1.744} = 9.75\ \text{ksi}$$

$F_{cy} = 20.0$ ksi

$$MS_{cy} = \frac{20.0}{9.75} - 1 = \underline{\underline{1.05}}$$

Compression Ultimate Stress at Tube Ends (Heat-affected Zone)

Ultimate Compressive Stress, $f_{cu} = 1.5\ f_{cy} = 1.5\ (9.75) = 14.62$ ksi

$F_{cu} = 24.0$ ksi

$$MS_{cu} = \frac{24.0}{14.62} - 1 = \underline{\underline{.64}}$$

DIAGONALS

The diagonal assembly consists of Kevlar cables with 17-4PH stainless steel end fittings. The same size cable is used for the top, side, and end diagonals.

Cable

Material: Kevlar

Limit Loads: Top Diagonals = 3.2 kips

Side Diagonals = 18.7 kips

End Diagonals = 21.9 kips

Size: PS29-6 x 37 x .85

Minimum Breaking Strength of Cable = 55.0 kips

End Fitting Efficiency = 75%

Ultimate Cable Assembly Strength = .75 (55.0) = 41.25 kips

Margins of Safety

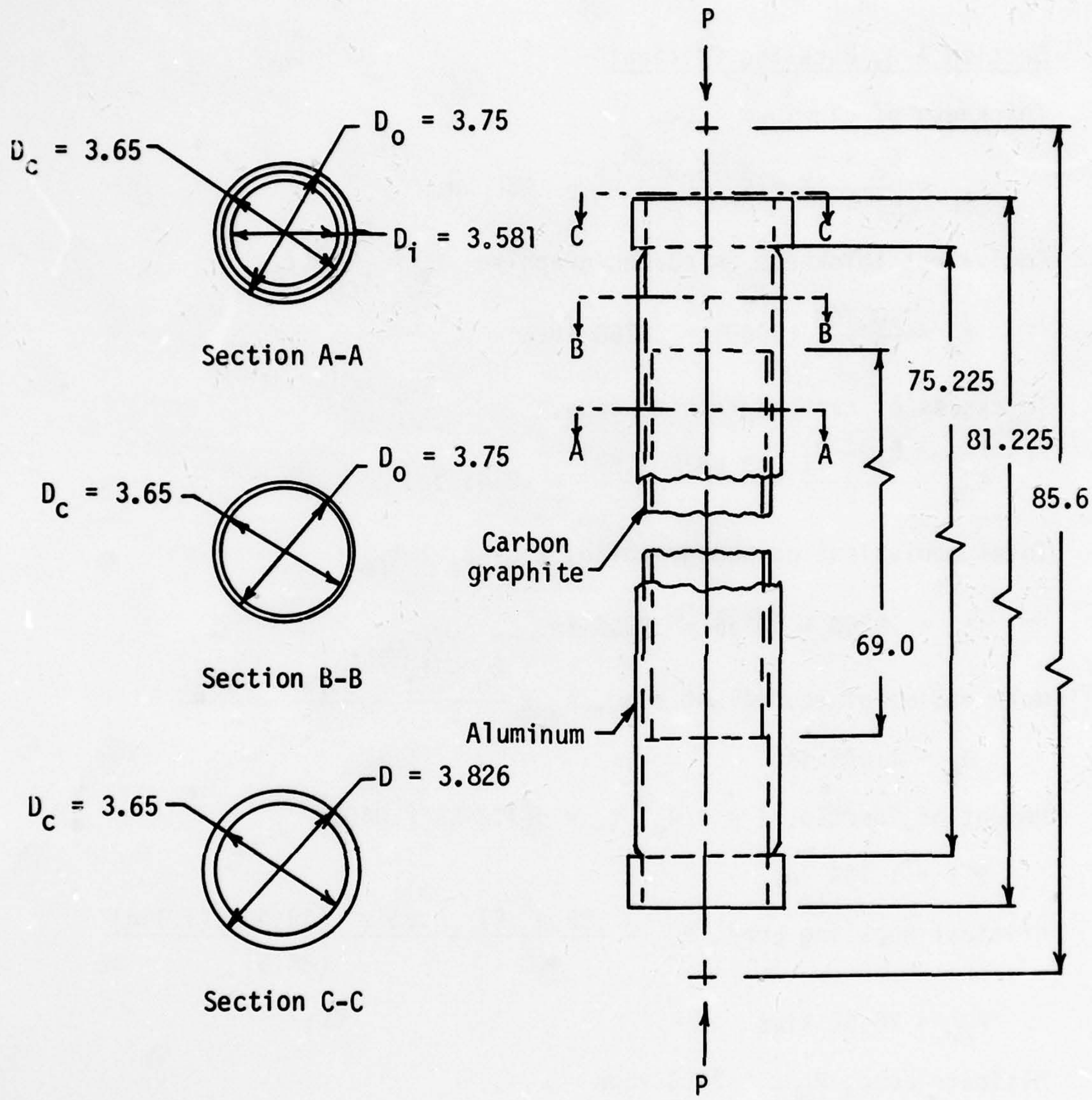
Top Diagonals: $MS_{tu} = \frac{41.25}{1.5\ (3.2)} - 1 = \underline{\underline{7.59}}$

Side Diagonals: $MS_{tu} = \frac{41.25}{1.5\ (18.7)} - 1 = \underline{\underline{.47}}$

End Diagonals: $MS_{tu} = \frac{41.25}{1.5\ (21.9)} - 1 = \underline{\underline{.26}}$

ALTERNATE ALUMINUM-CARBON/GRAPHITE COMPOSITE TUBE DESIGN

FOR THE HEGS-20 CORNER COLUMNS



Materials

Aluminum tube: 6061-T6

Carbon/graphite tube: Thornel 300/Narmco 5209, Carbon Fiber Prepreg System

Load

Limit Load = - 16.2 kips

Ultimate Load = 1.5 (- 16.2) = - 24.3 kips

Section A-A, Buckling Critical

Thickness of aluminum tube,

$$t_{AL} = \frac{D_o - D_c}{2} = \frac{3.75 - 3.65}{2} = .050 \text{ in.}$$

Equivalent thickness in carbon/graphite, $t_e = \frac{E_{AL}}{E_{CG}} (t_{AL})$

$$t_e = \frac{10,100}{19,400} (.050) = .0260 \text{ in.}$$

Thickness of carbon/graphite tube,

$$t_{CG} = \frac{E_c - D_i}{2} = \frac{3.65 - 3.581}{2} = .0345 \text{ in.}$$

Total equivalent carbon/graphite, $t_t = t_e + t_{CG}$

$$t_t = .0260 + .0345 = .0605 \text{ in.}$$

Mean radius of equivalent tube, $R_m = \frac{D_o - t_t}{2} = \frac{3.75 - .0605}{2}$

$$R_m = 1.845 \text{ in.}$$

Moment of inertia, $I = \pi R_m^3 t_t = \pi(1.845)^3(.0605)$

$$I = 1.194 \text{ in.}^4$$

Critical Buckling Load, $P_{cr} = \frac{.85 \pi^2 EI}{L^2} = \frac{.85 \pi^2 (19,400)(1.194)}{(85.6)^2}$

$$P_{cr} = 26.52 \text{ kips}$$

Ultimate Load, $P_{ULT} = 24.3$ kips

$$MS_{cu} = \frac{26.52}{24.3} - 1 = \underline{\underline{.09}}$$

Section B-B, Nominal Stress in Aluminum Tube

Area, $A = \frac{\pi}{4}\left[D_o^{\,2} - D_c^{\,2}\right] = \frac{\pi}{4}\left[(3.75)^2 - (3.65)^2\right]$

$A = .581 \text{ in.}^2$

Ultimate Compressive Stress, $f_{cu} = \frac{P_{ULT}}{A} = \frac{24.3}{.581}$

$f_{cu} = 41.8$ ksi

Allowable Ultimate Stress, $F_{cu} = 42.0$ ksi

$$MS = \frac{42.0}{41.8} - 1 = \underline{\underline{.005}}$$

Section C-C, Weld Attachment to End Fitting (Heat-affected Zone)

Area, $A = \frac{\pi}{4}\left[D^2 - D_c^{\,2}\right] = \frac{\pi}{4}\left[(3.826)^2 - (3.65)^2\right]$

$A = 1.033 \text{ in.}^2$

Ultimate Compressive Stress, $f_{cu} = \frac{P_{ULT}}{A} = \frac{24.3}{1.033}$

$f_{cu} = 23.52$ ksi

Allowable Ultimate Stress, $F_{cu} = 24.0$ ksi

$$MS_{cu} = \frac{24.0}{23.52} - 1 = \underline{\underline{.02}}$$

Weight of Aluminum-Carbon/Graphite Composite Tube

Weight, $W = \gamma AL$

End Rings	= .1 (1.033)(6) =	.620
Aluminum Tube	= .1 (.581)(75.225) =	4.370
Carbon/Graphite	= .056 (.392)(69.0) =	1.515
TOTAL WEIGHT, W_{COMP}		= 6.505 lbs

Weight of All-Aluminum Tube

Weight, $W = \gamma AL = .1\,(1.424)(81.225)$

$W_{ALUM} = 11.566$ lbs

Weight Saved by Using Aluminum-Carbon/Graphite Tube

$$\Delta W = W_{ALUM} - W_{COMP} = 11.566 - 6.505$$

$$\Delta W = 5.061 \text{ lbs/column}$$

or, for four columns/module:

$$\Delta W_t = 4\ (5.061) = 20.244 \text{ lbs/module}$$

FLOOR-BEAM GRID

The floor of the HEGS-Palletized is supported at its four corners and also at the midspans of the long sides. Figure A-24 shows the main structural beams of the floor. Like those in the HEGS-10 and HEGS-20, these beams are created by welding T-sections and angle-sections to the plate which forms the surface of the floor: thus, the floor surface itself becomes an integral part of the beams. There are:

1. Eight longitudinal beams which support interior loads
2. Three lateral beams which support the longitudinal beams and transfer load to the reaction points
3. Two lateral beams which interconnect the longitudinal beams at their midspans.

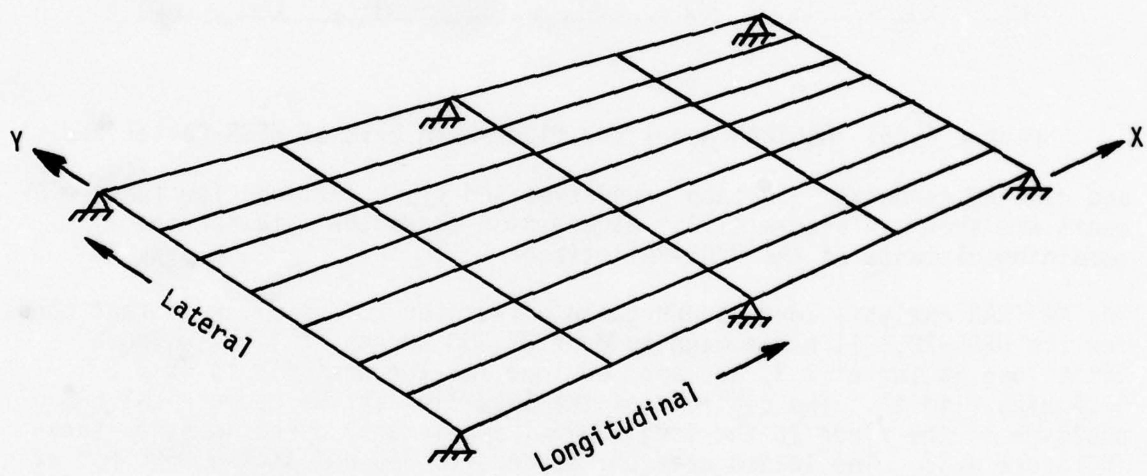


Figure A-24. Main floor-beam grid for HEGS-Palletized.

The structural integrity of the floor-beam grid was analyzed using NASTRAN. Figure A-25 shows the structural model with numbered modes and elements. Element numbers are circled.

The model for the HEGS-Palletized is basically the same as that used for the HEGS-10 and HEGS-20, with additional members to account for the increased width of the HEGS-Palletized. The edge beams (elements 1 through 4 and 66 through 71) and the T-beams (elements 1 through 34 and 60 through 65) have the same cross section as the corresponding elements in the HEGS-10

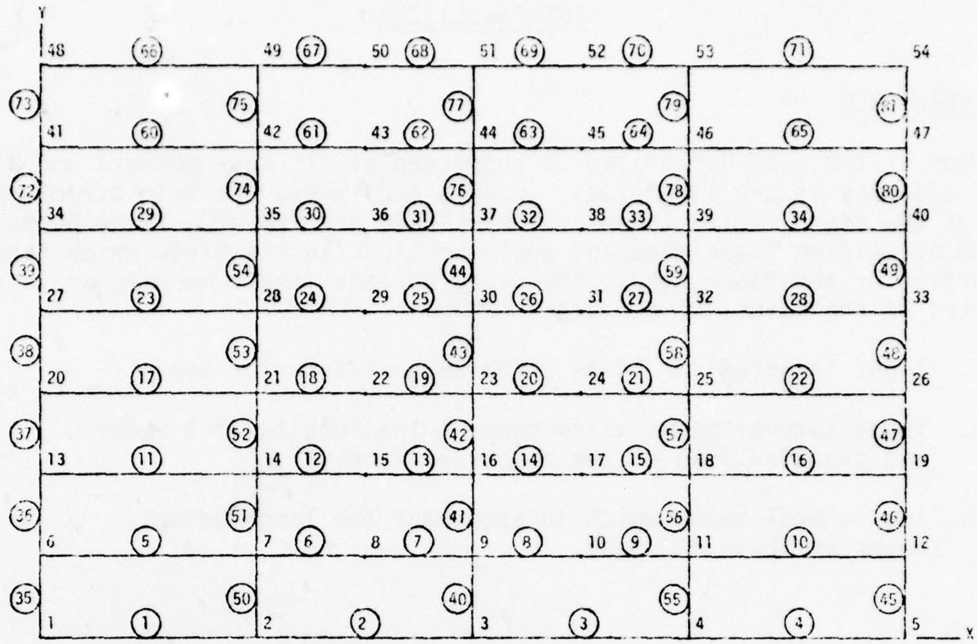


Figure A-25. NASTRAN model for floor-beam grid of HEGS-Palletized.

and HEGS-20 gondolas. Section properties and cross sections for these elements are shown in Figure A-13. Figure A-26 shows the data for the remaining elements of the HEGS-Palletized.

The NASTRAN analysis corresponds to an off-center load similar to that used for the HEGS-20. It has a magnitude of 25,000 pounds at 1-g. Using a limit load factor of 2.3, the applied load for the analysis is 25 x 2.3 = 57.5 kips (limit). The centroid of the load lies at the geometrical 60% position of the floor in the longitudinal and lateral directions, as shown in Figure A-27. The loaded area corresponds to 300 psf at 1-g, 690 psf at limit, and 1035 psf at ultimate.

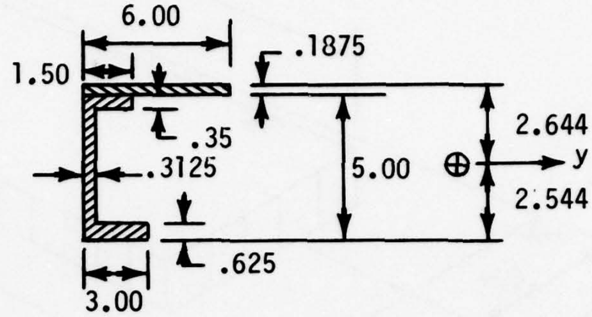
Members 35 through 39, 45 through 49, 72, 73, 80 and 81

End beams

$A = 4.783 \text{ in.}^2$

$I_y = 21.158 \text{ in.}^4$

$A_{web}/A_{total} = .339$



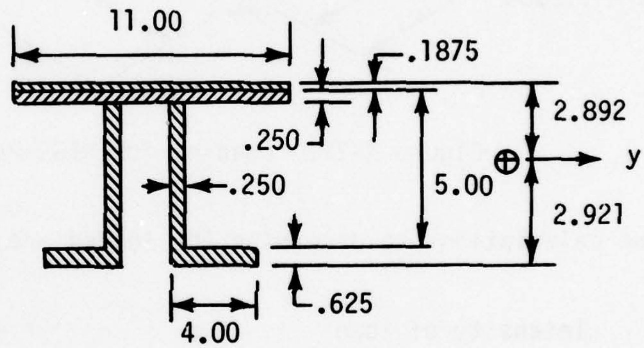
Members 40 through 44, 76 and 77

Center beam

$A = 12.186 \text{ in.}^2$

$I_y = 73.156 \text{ in.}^4$

$A_{web}/A_{total} = .238$



Members 50 through 59, 74, 75, 78 and 79

Sub-midspan beam

$A = 3.033 \text{ in.}^2$

$I_y = 14.776 \text{ in.}^4$

$A_{web}/A_{total} = .321$

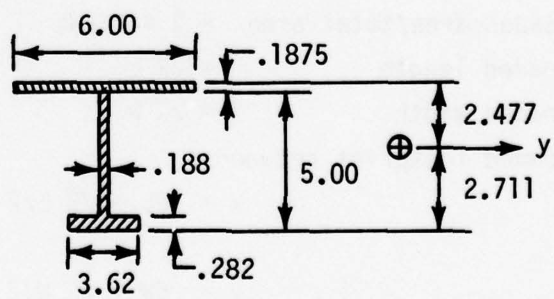


Figure A-26. Section properties and cross sections for elements of HEGS-Palletized.

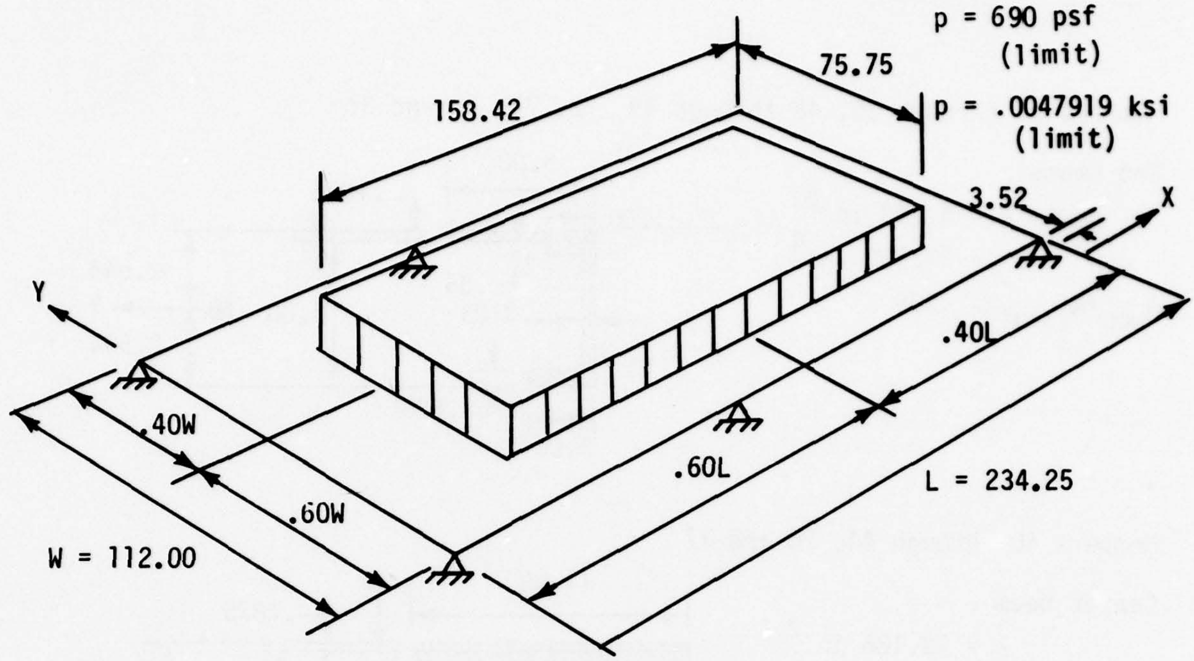
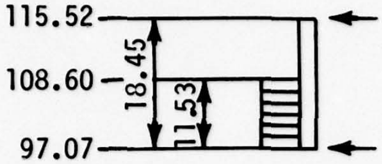


Figure A-27. Loading for HEGS-Palletized, case 3.01.

The calculations to determine the loaded area are:

Intensity of load	= p	= 300 psf at 1-g
Footprint of load	= P/p	= 25/.3 = 83.33 sq. ft.
Total floor area	= W/L	= 234.25 x 112/144
		= 182.19 sq. ft.
Loaded area/total area	= R = P/pWL	= 83.33/182.19 = .45738
Loaded length	= $\sqrt{R}$ L	= $\sqrt{.45738}$ x 234.25 = 158.42 in.
Loaded width	= $\sqrt{R}$ W	= $\sqrt{.45738}$ x 112.00 = 75.75 in.
Loaded footprint between:		
	x = .6L $\pm$ $\sqrt{R}$ L/2	= 140.55 $\pm$ 158.42/2;
		61.34 to 219.76 in.
	y = .6W $\pm$ $\sqrt{R}$ W/2	= 70.72 $\pm$ 75.75/2;
		32.84 to 108.60 in.

The corresponding loads acting upon the longitudinal beams of the NASTRAN model are calculated in Figure A-28.

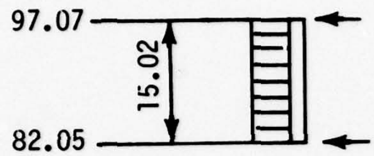


$$.05525 \times \frac{11.53}{2 \times 18.45} = .01726 \text{ k/in.}$$

total load = 11.53 x .0047919 = .05525 k/in.

.05525 - .01726 = .03799 k/in.

$$\begin{array}{r} .03799 \\ +\ .03599 \\ \hline .07398 \end{array} \text{ k/in.}$$



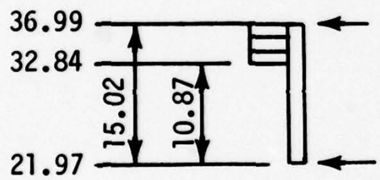
15.02 x .0047919 = .03599 k/in.

.03599

$$\begin{array}{r} .03599 \\ \times\ 2 \\ \hline .07198 \end{array} \text{ k/in.}$$

$$\begin{array}{r} .03599 \\ +\ .01714 \\ \hline .05313 \end{array} \text{ k/in.}$$

(.01989 - .00275) = .01714 k/in.



total load = (15.02 - 10.87) x .0047919
= .01989 k/in.

$$.01989 \times \frac{(15.02 - 10.87)}{2 \times 15.02} = .00275 \text{ k/in.}$$

Figure A-28. Loadings on beams of HEGS-Palletized, case 3.01.

Table A-9 presents the complete results from the NASTRAN analysis. The margins of safety are everywhere positive. The minimum margins of safety are:

.34 in the edge beams, member 71

.28 in the T-beams, member 65

.19 in the end beams, member 49

.04 in the sub-midspan beam, member 59

.05 in the center beam, member 44

TABLE A-9. HEGS-PALLETIZED FLOOR ANALYSIS

```
N A S T R A N   E X E C U T I V E   C O N T R O L   D E C K   E C H O

ID KAMAN, GONDOLA
SOL 1
TIME 2
DIAG 8,13,16
CEND

                         C A S E   C O N T R O L   D E C K   E C H O
CARD
COUNT
  1      TITLE = HEGS-PALLETIZED
  2      SUBCASE 1
  3         SUBTITLE = RUN 3.01, FLOOR GRID, LIMIT LOAD, 60-40 DIST., 690 PSF
  4         LOAD = 201
  5         DISP = ALL
  6         ELFO = ALL
  7         STRESS = ALL
  8         OLOAD = ALL
  9         SPCFORCES = ALL
 10      BEGIN BULK
        TOTAL COUNT=  204
```

TABLE A-9. HEGS-PALLETIZED FLOOR ANALYSIS (continued)

S O R T E D   B U L K   D A T A   E C H O

CARD COUNT	1	2	3	4	5	6	7	8	9	10
1-	CBAR	1	1	1	2	6			2	BC11
2-	+C11	5								
3-	CBAR	2	1	2	3	7			2	
4-	CBAR	3	1	3	4	9			2	
5-	CBAR	4	1	4	5	11			2	BC41
6-	+C41		5							
7-	CBAR	5	2	6	7	13			2	BC51
8-	+C51	4								
9-	CBAR	6	2	7	8	14			2	
10-	CBAR	7	2	8	9	15			2	
11-	CBAR	8	2	9	10	16			2	
12-	CBAR	9	2	10	11	17			2	
13-	CBAR	10	2	11	12	18			2	BC101
14-	+C101		5							
15-	CBAR	11	2	13	14	20			2	BC111
16-	+C111	5								
17-	CBAR	12	2	14	15	21			2	
18-	CBAR	13	2	15	16	22			2	
19-	CBAR	14	2	16	17	23			2	
20-	CBAR	15	2	17	18	24			2	
21-	CBAR	16	2	18	19	25			2	BC161
22-	+C161		5							
23-	CBAR	17	2	20	21	27			2	BC171
24-	+C171	5								
25-	CBAR	18	2	21	22	28			2	
26-	CBAR	19	2	22	23	29			2	
27-	CBAR	20	2	23	24	30			2	
28-	CBAR	21	2	24	25	31			2	
29-	CBAR	22	2	25	26	32			2	BC221
30-	+C221		5							
31-	CBAR	23	2	27	28	34			2	BC231
32-	+C231	5								
33-	CBAR	24	2	28	29	35			2	
34-	CBAR	25	2	29	30	36			2	
35-	CBAR	26	2	30	31	37			2	
36-	CBAR	27	2	31	32	38			2	
37-	CBAR	28	2	32	33	39			2	BC281
38-	+C281		5							
39-	CBAR	29	2	34	35	41			2	BC291
40-	+C291	5								
41-	CBAR	30	2	35	36	42			2	
42-	CBAR	31	2	36	37	43			2	
43-	CBAR	32	2	37	38	44			2	
44-	CBAR	33	2	38	39	45			2	
45-	CBAR	34	2	39	40	46			2	BC341
46-	+C341		5							
47-	CBAR	35	3	1	6	-100.	200.	.0	1	
48-	CBAR	36	3	6	13	-100.	200.	.0	1	
49-	CBAR	37	3	13	20	-100.	200.	.0	1	
50-	CBAR	38	3	20	27	-100.	200.	.0	1	

TABLE A-9. HEGS-PALLETIZED FLOOR ANALYSIS (continued)

SORTED BULK DATA ECHO

CARD COUNT	. 1 ..	2 ..	3 ..	4 ..	5 ..	6 ..	7 ..	8 ..	9 ..	10 .
51-	CHAR	39	3	27	34	-100.	200.	.0	1	
52-	CHAR	40	5	3	9	1			2	
53-	CHAR	41	5	9	16	6			2	
54-	CHAR	42	5	16	23	13			2	
55-	CHAR	43	5	23	30	20			2	
56-	CHAR	44	5	30	37	27			2	
57-	CHAR	45	3	5	12	3			2	
58-	CHAR	46	3	12	19	9			2	
59-	CHAR	47	3	19	26	16			2	
60-	CHAR	48	3	26	33	23			2	
61-	CHAR	49	3	33	40	30			2	
62-	CHAR	50	4	2	7	1			2	
63-	CHAR	51	4	7	14	6			2	
64-	CHAR	52	4	14	21	13			2	
65-	CHAR	53	4	21	28	20			2	
66-	CHAR	54	4	28	35	27			2	
67-	CHAR	55	4	4	11	3			2	
68-	CHAR	56	4	11	18	9			2	
69-	CHAR	57	4	18	25	16			2	
70-	CHAR	58	4	25	32	23			2	
71-	CHAR	59	4	32	39	30			2	
72-	CHAR	60	2	41	42	48			2	BC601
73-	+C601	5								
74-	CHAR	61	2	42	43	49			2	
75-	CHAR	62	2	43	44	50			2	
76-	CHAR	63	2	44	45	51			2	
77-	CHAR	64	2	45	46	52			2	
78-	CHAR	65	2	46	47	53			2	BC651
79-	+C651		5							
80-	CHAR	66	1	48	49	200.	200.	0.0	1	BC661
81-	+C661	5								
82-	CHAR	67	1	49	50	200.	200.	0.0	1	
83-	CHAR	68	1	50	51	200.	200.	0.0	1	
84-	CHAR	69	1	51	52	200.	200.	0.0	1	
85-	CHAR	70	1	52	53	200.	200.	0.0	1	
86-	CHAR	71	1	53	54	200.	200.	0.0	1	BC711
87-	+C711		5							
88-	CHAR	72	3	34	41	-100.	200.	0.0	1	
89-	CHAR	73	3	41	48	-100.	200.	0.0	1	
90-	CHAR	74	4	35	42	34			2	
91-	CHAR	75	4	42	49	41			2	
92-	CHAR	76	5	37	44	35			2	
93-	CHAR	77	5	44	51	42			2	
94-	CHAR	78	4	39	46	37			2	
95-	CHAR	79	4	46	53	44			2	
96-	CHAR	80	3	40	47	39			2	
97-	CHAR	81	3	47	54	46			2	
98-	GRID	1		.0	3.52	.0		1263		
99-	GRID	2		58.56	3.52	.0		126		
100-	GRID	3		117.12	3.52	.0		1263		

TABLE A-9. HEGS-PALLETIZED FLOOR ANALYSIS (continued)

SORTED BULK DATA ECHO

CARD COUNT	. 1 ..	2 ..	3 ..	4 ..	5 ..	6 ..	7 ..	8 ..	9 ..	10 .
101-	GRID	4		175.69	3.52	.0		126		
102-	GRID	5		234.25	3.52	.0		1263		
103-	GRID	6		.0	21.97	.0		126		
104-	GRID	7		58.56	21.97	.0		126		
105-	GRID	8		87.84	21.97	.0		126		
106-	GRID	9		117.12	21.97	.0		126		
107-	GRID	10		146.40	21.97	.0		126		
108-	GRID	11		175.68	21.97	.0		126		
109-	GRID	12		234.25	21.97	.0		126		
110-	GRID	13		.0	36.99	.0		126		
111-	GRID	14		58.56	36.99	.0		126		
112-	GRID	15		87.84	36.99	.0		126		
113-	GRID	16		117.12	36.99	.0		126		
114-	GRID	17		146.40	36.99	.0		126		
115-	GRID	18		175.68	36.99	.0		126		
116-	GRID	19		234.25	36.99	.0		126		
117-	GRID	20		.0	52.01	.0		126		
118-	GRID	21		58.56	52.01	.0		126		
119-	GRID	22		87.84	52.01	.0		126		
120-	GRID	23		117.12	52.01	.0		126		
121-	GRID	24		146.40	52.01	.0		126		
122-	GRID	25		175.68	52.01	.0		126		
123-	GRID	26		234.25	52.01	.0		126		
124-	GRID	27		.0	67.03	.0		126		
125-	GRID	28		58.56	67.03	.0		126		
126-	GRID	29		87.84	67.03	.0		126		
127-	GRID	30		117.12	67.03	.0		126		
128-	GRID	31		146.40	67.03	.0		126		
129-	GRID	32		175.68	67.03	.0		126		
130-	GRID	33		234.25	67.03	.0		126		
131-	GRID	34		.0	82.05	.0		126		
132-	GRID	35		58.56	82.05	.0		126		
133-	GRID	36		87.84	82.05	.0		126		
134-	GRID	37		117.12	82.05	.0		126		
135-	GRID	38		146.40	82.05	.0		126		
136-	GRID	39		175.68	82.05	.0		126		
137-	GRID	40		234.25	82.05	.0		126		
138-	GRID	41		.0	97.07	0.0		126		
139-	GRID	42		58.56	97.07	0.0		126		
140-	GRID	43		87.84	97.07	0.0		126		
141-	GRID	44		117.12	97.07	0.0		126		
142-	GRID	45		146.40	97.07	0.0		126		
143-	GRID	46		175.68	97.07	0.0		126		
144-	GRID	47		234.25	97.07	0.0		126		
145-	GRID	48		0.0	115.52	0.0		1263		
146-	GRID	49		58.56	115.52	0.0		126		
147-	GRID	50		87.84	115.52	0.0		126		
148-	GRID	51		117.12	115.52	0.0		1263		
149-	GRID	52		146.40	115.52	0.0		126		
150-	GRID	53		175.68	115.52	0.0		126		

TABLE A-9. HEGS-PALLETIZED FLOOR ANALYSIS (continued)

SORTED BULK DATA ECHO

CARD COUNT	. 1 ..	2 ..	3 ..	4 ..	5 ..	6 ..	7 ..	8 ..	9 ..	10
151-	GRID	54		234.25	115.52	0.0		1263		
152-	MAT1	1	10400.	4000.						MA11
153-	+A11	26.0	27.0	15.						
154-	PBAR	1	1	3.375	1.	14.143	.1			PB11
155-	+B11	.0	2.562	.0	-2.625					PB12
156-	+B12	.480	.480							
157-	PBAR	2	1	2.904	1.	13.331	.1			PB21
158-	+B21	.0	2.046	.0	-3.142					PB22
159-	+B22	.336	.336							
160-	PBAR	3	1	4.783	1.	21.158	.1			PB31
161-	+B31	.0	2.644	.0	-2.544					PB32
162-	+B32	.339	.339							
163-	PBAR	4	1	3.033	1.	14.776	.1			PB41
164-	+B41	.0	2.477	.0	-2.711					PB42
165-	+B42	.321	.321							
166-	PBAR	5	1	12.186	1.	73.156	.1			PB51
167-	+B51	.0	2.892	.0	-2.921					PB52
168-	+B52	.238	.238							
169-	PLOAD1	201	6	FZ	FR	.0949	-.00275	1.00	-.00275	
170-	PLOAD1	201	7	FZ	FR	.0000	-.00275	1.00	-.00275	
171-	PLOAD1	201	8	FZ	FR	.0000	-.00275	1.00	-.00275	
172-	PLOAD1	201	9	FZ	FR	.0000	-.00275	1.00	-.00275	
173-	PLOAD1	201	10	FZ	FR	.0000	-.00275	.7526	-.00275	
174-	PLOAD1	201	12	FZ	FR	.0949	-.05313	1.00	-.05313	
175-	PLOAD1	201	13	FZ	FR	.0000	-.05313	1.00	-.05313	
176-	PLOAD1	201	14	FZ	FR	.0000	-.05313	1.00	-.05313	
177-	PLOAD1	201	15	FZ	FR	.0000	-.05313	1.00	-.05313	
178-	PLOAD1	201	16	FZ	FR	.0000	-.05313	.7526	-.05313	
179-	PLOAD1	201	18	FZ	FR	.0949	-.07198	1.00	-.07198	
180-	PLOAD1	201	19	FZ	FR	.000	-.07198	1.00	-.07198	
181-	PLOAD1	201	20	FZ	FR	.000	-.07198	1.00	-.07198	
182-	PLOAD1	201	21	FZ	FR	.000	-.07198	1.00	-.07198	
183-	PLOAD1	201	22	FZ	FR	.000	-.07198	.7526	-.07198	
184-	PLOAD1	201	24	FZ	FR	.0949	-.07198	1.00	-.07198	
185-	PLOAD1	201	25	FZ	FR	.0000	-.07198	1.00	-.07198	
186-	PLOAD1	201	26	FZ	FR	.0000	-.07198	1.00	-.07198	
187-	PLOAD1	201	27	FZ	FR	.0000	-.07198	1.00	-.07198	
188-	PLOAD1	201	28	FZ	FR	.0000	-.07198	.7526	-.07198	
189-	PLOAD1	201	30	FZ	FR	.0949	-.07198	1.00	-.07198	
190-	PLOAD1	201	31	FZ	FR	.0000	-.07198	1.00	-.07198	
191-	PLOAD1	201	32	FZ	FR	.0000	-.07198	1.00	-.07198	
192-	PLOAD1	201	33	FZ	FR	.0000	-.07198	1.00	-.07198	
193-	PLOAD1	201	34	FZ	FR	.0000	-.07198	.7526	-.07198	
194-	PLOAD1	201	61	FZ	FR	.0949	-.07398	1.00	-.07398	
195-	PLOAD1	201	62	FZ	FR	.0000	-.07398	1.00	-.07398	
196-	PLOAD1	201	63	FZ	FR	.0000	-.07398	1.00	-.07398	
197-	PLOAD1	201	64	FZ	FR	.0000	-.07398	1.00	-.07398	
198-	PLOAD1	201	65	FZ	FR	.0000	-.07398	.7526	-.07398	
199-	PLOAD1	201	67	FZ	FR	.0949	-.01726	1.00	-.01726	
200-	PLOAD1	201	68	FZ	FR	.0	-.01726	1.00	-.01726	

TABLE A-9. HEGS-PALLETIZED FLOOR ANALYSIS (continued)

D I S P L A C E M E N T   V E C T O R

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
1	G	0.0	0.0	0.0	-1.871044E-03	5.936250E-03	0.0
2	G	0.0	0.0	-6.751157E-02	-1.474376E-02	-1.135583E-03	0.0
3	G	0.0	0.0	0.0	-2.799029E-02	2.616807E-03	0.0
4	G	0.0	0.0	-2.757776E-01	-3.106835E-02	1.139314E-03	0.0
5	G	0.0	0.0	0.0	-2.863783E-02	0.0	0.0
6	G	0.0	0.0	-3.376759E-02	-1.586533E-03	5.936250E-03	0.0
7	G	0.0	0.0	-3.370599E-01	-1.342370E-02	3.514499E-03	0.0
8	G	0.0	0.0	-4.158530E-01	-1.904579E-02	2.679217E-03	0.0
9	G	0.0	0.0	-5.196247E-01	-2.466789E-02	5.344673E-03	0.0
10	G	0.0	0.0	-7.170064E-01	-2.671443E-02	6.394597E-03	0.0
11	G	0.0	0.0	-8.446903E-01	-2.870946E-02	7.081383E-04	0.0
12	G	0.0	0.0	-5.197290E-01	-2.514729E-02	0.0	0.0
13	G	0.0	0.0	-5.412276E-02	-1.046009E-03	5.936250E-03	0.0
14	G	0.0	0.0	-5.228298E-01	-9.886667E-03	7.312057E-03	0.0
15	G	0.0	0.0	-7.084784E-01	-1.360548E-02	5.191541E-03	0.0
16	G	0.0	0.0	-8.567130E-01	-1.732429E-02	7.151987E-03	0.0
17	G	0.0	0.0	-1.116174E+00	-1.979291E-02	7.593476E-03	0.0
18	G	0.0	0.0	-1.249160E+00	-2.226153E-02	9.133888E-04	0.0
19	G	0.0	0.0	-8.538168E-01	-1.754279E-02	0.0	0.0
20	G	0.0	0.0	-6.509769E-02	-3.765007E-04	5.936250E-03	0.0
21	G	0.0	0.0	-6.346248E-01	-4.079186E-03	9.201930E-03	0.0
22	G	0.0	0.0	-8.713672E-01	-5.461331E-03	6.531098E-03	0.0
23	G	0.0	0.0	-1.051739E+00	-6.843475E-03	8.596955E-03	0.0
24	G	0.0	0.0	-1.362138E+00	-9.037167E-03	8.931582E-03	0.0
25	G	0.0	0.0	-1.514599E+00	-1.123086E-02	1.060959E-03	0.0
26	G	0.0	0.0	-1.045183E+00	-6.837948E-03	0.0	0.0
27	G	0.0	0.0	-6.539466E-02	3.463058E-04	5.936250E-03	0.0
28	G	0.0	0.0	-6.456181E-01	2.716562E-03	9.165915E-03	0.0
29	G	0.0	0.0	-8.792166E-01	3.913323E-03	6.526716E-03	0.0
30	G	0.0	0.0	-1.067776E+00	5.110084E-03	9.334903E-03	0.0
31	G	0.0	0.0	-1.410710E+00	3.458748E-03	1.006940E-02	0.0
32	G	0.0	0.0	-1.587078E+00	1.807413E-03	1.209421E-03	0.0
33	G	0.0	0.0	-1.058516E+00	5.295587E-03	0.0	0.0
34	G	0.0	0.0	-5.471508E-02	1.043245E-03	5.936250E-03	0.0
35	G	0.0	0.0	-5.528970E-01	9.018033E-03	7.487300E-03	0.0
36	G	0.0	0.0	-7.357759E-01	1.281716E-02	5.039422E-03	0.0
37	G	0.0	0.0	-8.965571E-01	1.661629E-02	9.223336E-03	0.0
38	G	0.0	0.0	-1.258610E+00	1.529500E-02	1.104635E-02	0.0
39	G	0.0	0.0	-1.460123E+00	1.397370E-02	1.509590E-03	0.0
40	G	0.0	0.0	-8.863355E-01	1.643112E-02	0.0	0.0
41	G	0.0	0.0	-3.414759E-02	1.605441E-03	5.936250E-03	0.0
42	G	0.0	0.0	-3.742912E-01	1.361015E-02	4.341058E-03	0.0
43	G	0.0	0.0	-4.615507E-01	1.962209E-02	2.089732E-03	0.0
44	G	0.0	0.0	-5.593352E-01	2.563404E-02	8.395594E-03	0.0
45	G	0.0	0.0	-9.340772E-01	2.429447E-02	1.209376E-02	0.0
46	G	0.0	0.0	-1.166548E+00	2.295491E-02	2.020035E-03	0.0
47	G	0.0	0.0	-5.511466E-01	2.600767E-02	0.0	0.0
48	G	0.0	0.0	0.0	1.892138E-03	5.936250E-03	0.0
49	G	0.0	0.0	-8.780535E-02	1.574440E-02	-2.205178E-03	0.0
50	G	0.0	0.0	2.055531E-02	2.291392E-02	-3.065379E-03	0.0
51	G	0.0	0.0	0.0	3.008338E-02	7.246375E-03	0.0
52	G	0.0	0.0	-3.748949E-01	2.863435E-02	1.404202E-02	0.0
53	G	0.0	0.0	-6.729376E-01	2.718532E-02	2.643831E-03	0.0
54	G	0.0	0.0	0.0	3.046965E-02	0.0	0.0

TABLE A-9. HEGS-PALLETIZED FLOOR ANALYSIS (continued)

L O A D   V E C T O R

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
7	G	0.0	0.0	-3.278285E-02	0.0	1.885920E-01	0.0
8	G	0.0	0.0	-8.035581E-02	0.0	2.067958E-03	0.0
9	G	0.0	0.0	-8.052000E-02	0.0	-8.881784E-15	0.0
10	G	0.0	0.0	-8.052000E-02	0.0	-1.776357E-15	0.0
11	G	0.0	0.0	-1.330742E-01	0.0	6.114999E-01	0.0
12	G	0.0	0.0	-2.640522E-02	0.0	0.0	0.0
14	G	0.0	0.0	-6.333646E-01	0.0	3.643598E+00	0.0
15	G	0.0	0.0	-1.552474E+00	0.0	3.995295E-02	0.0
16	G	0.0	0.0	-1.555646E+00	0.0	-1.847411E-13	0.0
17	G	0.0	0.0	-1.555646E+00	0.0	-5.684342E-14	0.0
18	G	0.0	0.0	-2.570993E+00	0.0	1.567818E+01	0.0
19	G	0.0	0.0	-5.487688E-01	0.0	0.0	0.0
21	G	0.0	0.0	-8.580761E-01	0.0	4.936310E+00	0.0
22	G	0.0	0.0	-2.103277E+00	0.0	5.412787E-02	0.0
23	G	0.0	0.0	-2.107574E+00	0.0	-2.273737E-13	0.0
24	G	0.0	0.0	-2.107574E+00	0.0	-5.684342E-14	0.0
25	G	0.0	0.0	-3.483156E+00	0.0	2.124064E+01	0.0
26	G	0.0	0.0	-7.434937E-01	0.0	0.0	0.0
28	G	0.0	0.0	-8.580761E-01	0.0	4.936310E+00	0.0
29	G	0.0	0.0	-2.103277E+00	0.0	5.412787E-02	0.0
30	G	0.0	0.0	-2.107574E+00	0.0	-2.273737E-13	0.0
31	G	0.0	0.0	-2.107574E+00	0.0	-5.684342E-14	0.0
32	G	0.0	0.0	-3.483156E+00	0.0	2.124064E+01	0.0
33	G	0.0	0.0	-7.434937E-01	0.0	0.0	0.0
35	G	0.0	0.0	-8.580761E-01	0.0	4.936310E+00	0.0
36	G	0.0	0.0	-2.103277E+00	0.0	5.412787E-02	0.0
37	G	0.0	0.0	-2.107574E+00	0.0	-2.273737E-13	0.0
38	G	0.0	0.0	-2.107574E+00	0.0	-5.684342E-14	0.0
39	G	0.0	0.0	-3.483156E+00	0.0	2.124064E+01	0.0
40	G	0.0	0.0	-7.434937E-01	0.0	0.0	0.0
42	G	0.0	0.0	-8.819181E-01	0.0	5.073468E+00	0.0
43	G	0.0	0.0	-2.161717E+00	0.0	5.563183E-02	0.0
44	G	0.0	0.0	-2.166134E+00	0.0	-2.273737E-13	0.0
45	G	0.0	0.0	-2.166134E+00	0.0	-8.526513E-14	0.0
46	G	0.0	0.0	-3.579937E+00	0.0	2.183082E+01	0.0
47	G	0.0	0.0	-7.641521E-01	0.0	0.0	0.0
49	G	0.0	0.0	-2.055874E-01	0.0	1.181189E+00	0.0
50	G	0.0	0.0	-5.045119E-01	0.0	1.045617E-02	0.0
51	G	0.0	0.0	-5.053728E-01	0.0	-4.973799E-14	0.0
52	G	0.0	0.0	-5.053728E-01	0.0	-2.131628E-14	0.0
53	G	0.0	0.0	-8.364097E-01	0.0	5.162835E+00	0.0
54	G	0.0	0.0	-1.770937E-01	0.0	0.0	0.0

F O R C E S   O F   S I N G L E - P O I N T   C O N S T R A I N T

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
1	G	0.0	0.0	6.470401E-01	0.0	0.0	0.0
3	G	0.0	0.0	1.711115E+01	0.0	0.0	0.0
5	G	0.0	0.0	5.248830E+00	0.0	0.0	0.0
48	G	0.0	0.0	8.278026E-01	0.0	0.0	0.0
51	G	0.0	0.0	2.595080E+01	0.0	0.0	0.0
54	G	0.0	0.0	7.730746E+00	0.0	0.0	0.0

TABLE A-9. HEGS-PALLETIZED FLOOR ANALYSIS (continued)

F O R C E S   I N   B A R   E L E M E N T S   (C B A R)

ELEMENT ID.	BEND-MOMENT END-A PLANE 1	BEND-MOMENT END-A PLANE 2	BEND-MOMENT END-B PLANE 1	BEND-MOMENT END-B PLANE 2	- SHEAR - PLANE 1	- SHEAR - PLANE 2	AXIAL FORCE	TORQUE
1	0.0	0.0	0.0	1.690889E+01	0.0	-2.887447E-01	0.0	-8.792841E-02
2	0.0	1.700970E+01	0.0	-3.566022E+01	0.0	9.028334E-01	0.0	-9.048172E-02
3	0.0	-3.580109E+01	0.0	4.322195E+01	0.0	-1.349207E+00	0.0	-2.102140E-02
4	0.0	4.321256E+01	0.0	-4.547474E-13	0.0	7.379194E-01	0.0	1.660189E-02
5	0.0	-9.094947E-13	0.0	1.146712E+01	0.0	-1.958184E-01	0.0	0.0
6	0.0	1.165603E+01	0.0	-3.745817E+00	0.0	5.260194E-01	0.0	-7.680457E-02
7	0.0	-3.743749E+00	0.0	-2.149842E+01	0.0	6.063752E-01	0.0	-7.680457E-02
8	0.0	-2.150943E+01	0.0	1.156653E+01	0.0	-1.129643E+00	0.0	-2.795832E-02
9	0.0	1.156653E+01	0.0	4.228486E+01	0.0	-1.049123E+00	0.0	-2.795832E-02
10	0.0	4.309035E+01	0.0	-9.094947E-13	0.0	7.357066E-01	0.0	2.467947E-02
11	0.0	4.922437E-14	0.0	4.765613E+00	0.0	-8.133000E-02	0.0	-6.034701E-02
12	0.0	8.358407E+00	0.0	1.172310E+01	0.0	-1.149145E-01	0.0	-5.080345E-02
13	0.0	1.176306E+01	0.0	-3.032869E+01	0.0	1.437560E+00	0.0	-5.080345E-02
14	0.0	-3.033834E+01	0.0	2.615738E+01	0.0	-1.929499E+00	0.0	-3.372432E-02
15	0.0	2.615738E+01	0.0	3.710378E+01	0.0	-3.738522E-01	0.0	-3.372432E-02
16	0.0	5.278042E+01	0.0	4.547474E-13	0.0	9.011511E-01	0.0	3.222[illegible]E-02
17	0.0	5.920601E-14	0.0	3.606837E+00	0.0	-6.159216E-02	0.0	-2.529157E-02
18	0.0	8.491859E+00	0.0	1.680122E+01	0.0	-2.837845E-01	0.0	-1.888175E-02
19	0.0	1.685534E+01	0.0	-3.641924E+01	0.0	1.819487E+00	0.0	-1.888175E-02
20	0.0	-3.643807E+01	0.0	3.326912E+01	0.0	-2.380710E+00	0.0	-2.996848E-02
21	0.0	3.326912E+01	0.0	4.126654E+01	0.0	-2.731357E-01	0.0	-2.996848E-02
22	0.0	6.250720E+01	0.0	-1.364242E-12	0.0	1.067222E+00	0.0	3.000111E-02
23	0.0	5.947610E-14	0.0	5.113156E+00	0.0	-8.731483E-02	0.0	1.619028E-02
24	0.0	1.000572E+01	0.0	1.496884E+01	0.0	-1.695053E-01	0.0	1.634919E-02
25	0.0	1.502296E+01	0.0	-4.159786E+01	0.0	1.933771E+00	0.0	1.634919E-02
26	0.0	-4.162049E+01	0.0	3.466475E+01	0.0	-2.605370E+00	0.0	-2.255923E-02
27	0.0	3.466475E+01	0.0	4.924020E+01	0.0	-4.977956E-01	0.0	-2.255923E-02
28	0.0	7.048488E+01	0.0	-9.094947E-13	0.0	1.203430E+00	0.0	2.382220E-02
29	0.0	4.976307E-14	0.0	7.025636E+00	0.0	-1.199733E-01	0.0	5.447260E-02
30	0.0	1.192286E+01	0.0	1.125881E+01	0.0	2.267942E-02	0.0	5.190065E-02
31	0.0	1.131294E+01	0.0	-5.093506E+01	0.0	2.125956E+00	0.0	5.190065E-02
32	0.0	-5.095413E+01	0.0	3.358995E+01	0.0	-2.890850E+00	0.0	-1.805043E-02
33	0.0	3.358995E+01	0.0	5.662425E+01	0.0	-7.832756E-01	0.0	-1.805043E-02
34	0.0	7.787049E+01	0.0	-9.094947E-13	0.0	1.329529E+00	0.0	2.019748E-02
35	0.0	8.792841E-02	0.0	6.698480E+00	0.0	-3.582955E-01	0.0	0.0
36	0.0	6.698480E+00	0.0	9.138886E+00	0.0	-1.624771E-01	0.0	-4.084981E-14
37	0.0	9.149273E+00	0.0	1.041735E+01	0.0	-8.109711E-02	0.0	-4.085621E-14
38	0.0	1.044264E+01	0.0	1.073561E+01	0.0	-1.950494E-02	0.0	-3.375078E-14
39	0.0	1.071942E+01	0.0	9.700912E+00	0.0	6.780989E-02	0.0	-2.220446E-14
40	0.0	-6.946032E-02	0.0	2.740811E+02	0.0	-1.485911E+01	0.0	5.914074E-02
41	0.0	2.740321E+02	0.0	4.699317E+02	0.0	-1.394257E+01	0.0	4.813045E-02
42	0.0	4.699147E+02	0.0	5.918751E+02	0.0	-8.119868E+00	0.0	3.848119E-02
43	0.0	5.918852E+02	0.0	6.191039E+02	0.0	-1.812096E+00	0.0	1.965241E-02
44	0.0	6.191428E+02	0.0	5.465268E+02	0.0	4.834619E+00	0.0	-2.971162E-03
45	0.0	1.660169E-02	0.0	8.324289E+01	0.0	-4.510910E+00	0.0	0.0
46	0.0	8.326757E+01	0.0	1.395445E+02	0.0	-3.746798E+00	0.0	0.0
47	0.0	1.395767E+02	0.0	1.740755E+02	0.0	-2.296858E+00	0.0	0.0
48	0.0	1.741055E+02	0.0	1.814074E+02	0.0	-4.861424E-01	0.0	0.0
49	0.0	1.814312E+02	0.0	1.594903E+02	0.0	1.460781E+00	0.0	0.0
50	0.0	2.553313E-03	0.0	2.198717E+01	0.0	-1.191578E+00	0.0	1.008170E-01

TABLE A-9. HEGS-PALLETIZED FLOOR ANALYSIS (continued)

FORCES IN BAR ELEMENTS (CBAR)

ELEMENT ID.	BEND-MOMENT END-A PLANE 1	BEND-MOMENT END-A PLANE 2	BEND-MOMENT END-B PLANE 1	BEND-MOMENT END-B PLANE 2	- SHEAR - PLANE 1	- SHEAR - PLANE 2	AXIAL FORCE	TORQUE
51	0.0	2.206397E+01	0.0	5.031108E+01	0.0	-1.880633E+00	0.0	1.011334E-01
52	0.0	5.030150E+01	0.0	6.853178E+01	0.0	-1.213734E+00	0.0	5.032452E-02
53	0.0	6.852537E+01	0.0	7.052995E+01	0.0	-1.334605E-01	0.0	-9.591302E-04
54	0.0	7.052979E+01	0.0	5.841156E+01	0.0	8.068060E-01	0.0	-4.470346E-02
55	0.0	-3.762838E-02	0.0	3.846985E+01	0.0	-2.087126E+00	0.0	-9.375099E-03
56	0.0	3.841721E+01	0.0	9.457522E+01	0.0	-3.738882E+00	0.0	5.460559E-03
57	0.0	9.450927E+01	0.0	1.312015E+02	0.0	-2.442892E+00	0.0	3.929555E-03
58	0.0	1.311415E+02	0.0	1.356489E+02	0.0	-3.000937E-01	0.0	3.453722E-03
59	0.0	1.356026E+02	0.0	1.133454E+02	0.0	1.481837E+00	0.0	7.993446E-03
60	0.0	3.105705E-14	0.0	1.010824E+01	0.0	-1.726134E-01	0.0	8.199938E-02
61	0.0	1.512358E+01	0.0	5.196731E+00	0.0	3.048786E-01	0.0	8.213037E-02
62	0.0	6.252363E+00	0.0	-6.546956E+01	0.0	2.466596E+00	0.0	6.213037E-02
63	0.0	-6.597244E+01	0.0	3.095041E+01	0.0	-3.310207E+00	0.0	-1.830004E-02
64	0.0	3.095041E+01	0.0	6.444884E+01	0.0	-1.144072E+00	0.0	-1.830004E-02
65	0.0	8.627960E+01	0.0	-4.547474E-13	0.0	1.473102E+00	0.0	2.064864E-02
66	0.0	0.0	0.0	2.737130E+01	0.0	-4.674060E-01	0.0	9.461470E-02
67	0.0	2.869441E+01	0.0	-2.005202E+01	0.0	1.654837E+00	0.0	9.794345E-02
68	0.0	-2.004152E+01	0.0	-8.356006E+01	0.0	2.169349E+00	0.0	9.794345E-02
69	0.0	-8.353514E+01	0.0	1.525970E+01	0.0	-3.374141E+00	0.0	-1.979551E-02
70	0.0	1.525970E+01	0.0	9.925722E+01	0.0	-2.868768E+00	0.0	-1.979551E-02
71	0.0	1.044065E+02	0.0	4.547474E-13	0.0	1.782594E+00	0.0	2.243011E-02
72	0.0	9.646440E+00	0.0	6.825937E+00	0.0	1.877832E-01	0.0	-1.332266E-14
73	0.0	6.743937E+00	0.0	9.461970E-02	0.0	3.603966E-01	0.0	-6.217249E-15
74	0.0	5.841413E+01	0.0	3.555025E+01	0.0	1.522229E+00	0.0	-8.370806E-02
75	0.0	3.555012E+01	0.0	3.323751E-03	0.0	1.926656E+00	0.0	-1.419734E-01
76	0.0	5.465957E+02	0.0	3.669726E+02	0.0	1.195900E+01	0.0	-2.204374E-02
77	0.0	3.670730E+02	0.0	-1.177390E-01	0.0	1.990194E+01	0.0	-2.491530E-02
78	0.0	1.133071E+02	0.0	7.046724E+01	0.0	2.852189E+00	0.0	1.359375E-02
79	0.0	7.042809E+01	0.0	4.222562E-02	0.0	3.814952E+00	0.0	1.352403E-02
80	0.0	1.595105E+02	0.0	1.064327E+02	0.0	3.533803E+00	0.0	0.0
81	0.0	1.064536E+02	0.0	-2.243011E-02	0.0	5.771058E+00	0.0	0.0

TABLE A-9. HEGS-PALLETIZED FLOOR ANALYSIS (continued)

	S T R E S S E S I N B A R E L E M E N T S				(C B A R)		
ELEMENT ID.	SA1 SB1	SA2 SB2	SA3 SB3	SA4 SB4	AXIAL STRESS	SA-MAX SB-MAX	SA-MIN SB-MIN	M.S.-T M.S.-C
1	0.0 -3.063040E+00	0.0 3.138360E+00	0.0 0.0	0.0 0.0	0.0	0.0 3.138360E+00	0.0 -3.063040E+00	7.3E+00 7.8E+00
2	-3.081302E+00 6.496068E+00	3.157072E+00 -6.655807E+00	0.0 0.0	0.0 0.0	0.0	3.157072E+00 6.496068E+00	-3.081302E+00 -6.655807E+00	3.0E+00 3.1E+00
3	6.485355E+00 -7.829643E+00	-6.644831E+00 8.022175E+00	0.0 0.0	0.0 0.0	0.0	6.485355E+00 8.022175E+00	-6.644831E+00 -7.829643E+00	2.2E+00 2.4E+00
4	-7.827941E+00 8.237734E-14	8.020432E+00 -8.440301E-14	0.0 0.0	0.0 0.0	0.0	8.020432E+00 8.237734E-14	-7.827941E+00 -8.440301E-14	2.2E+00 2.4E+00
5	1.395864E-13 -1.759938E+00	-2.143599E-13 2.702701E+00	0.0 0.0	0.0 0.0	0.0	1.395864E-13 2.702701E+00	-2.143599E-13 -1.759938E+00	8.6E+00 1.4E+01
6	-1.788931E+00 5.748962E-01	2.747225E+00 -8.828562E-01	0.0 0.0	0.0 0.0	0.0	2.747225E+00 5.748962E-01	-1.788931E+00 -8.828562E-01	8.5E+00 1.4E+01
7	5.745788E-01 3.299509E+00	-8.823688E-01 -5.066988E+00	0.0 0.0	0.0 0.0	0.0	5.745788E-01 3.299509E+00	-8.823688E-01 -5.066988E+00	6.9E+00 4.3E+00
8	3.301199E+00 -1.775195E+00	-5.069583E+00 2.726130E+00	0.0 0.0	0.0 0.0	0.0	3.301199E+00 2.726130E+00	-5.069583E+00 -1.775195E+00	6.9E+00 4.3E+00
9	-1.775195E+00 -6.489747E+00	2.726130E+00 9.966171E+00	0.0 0.0	0.0 0.0	0.0	2.726130E+00 9.966171E+00	-1.775195E+00 -6.489747E+00	1.6E+00 3.2E+00
10	-6.613371E+00 1.395864E-13	1.015602E+01 -2.143599E-13	0.0 0.0	0.0 0.0	0.0	1.015602E+01 1.395864E-13	-6.613371E+00 -2.143599E-13	1.6E+00 3.1E+00
11	-7.554801E-15 -7.314113E-01	1.160175E-14 1.123213E+00	0.0 0.0	0.0 0.0	0.0	1.160175E-14 1.123213E+00	-7.554801E-15 -7.314113E-01	2.2E+01 3.6E+01
12	-1.282822E+00 -1.799225E+00	1.970003E+00 2.763033E+00	0.0 0.0	0.0 0.0	0.0	1.970003E+00 2.763033E+00	-1.282822E+00 -1.799225E+00	5.4E+00 1.4E+01
13	-1.805357E+00 4.654752E+00	2.772450E+00 -7.148206E+00	0.0 0.0	0.0 0.0	0.0	2.772450E+00 4.654752E+00	-1.805357E+00 -7.148206E+00	4.6E+00 2.8E+00
14	4.656233E+00 -4.014553E+00	-7.150481E+00 6.165066E+00	0.0 0.0	0.0 0.0	0.0	4.656233E+00 6.165066E+00	-7.150481E+00 -4.014553E+00	3.2E+00 2.8E+00
15	-4.014553E+00 -5.694571E+00	6.165066E+00 8.745035E+00	0.0 0.0	0.0 0.0	0.0	6.165066E+00 8.745035E+00	-4.014553E+00 -5.694571E+00	2.0E+00 3.7E+00
16	-8.100573E+00 -6.979319E-14	1.243988E+01 1.071800E-13	0.0 0.0	0.0 0.0	0.0	1.243988E+01 1.071800E-13	-8.100573E+00 -6.979319E-14	1.1E+00 2.3E+00

TABLE A-9. HEGS-PALLETIZED FLOOR ANALYSIS (continued)

	S T R E S S E S	I N	B A R	E L E M E N T S		(C B A R)		
ELEMENT ID.	SA1 SB1	SA2 SB2	SA3 SB3	SA4 SB4	AXIAL STRESS	SA-MAX SB-MAX	SA-MIN SB-MIN	M.S.-T M.S.-C
17	-9.086752E-15 -5.535660E-01	1.395434E-14 8.500999E-01	0.0 0.0	0.0 0.0	0.0	1.395434E-14 8.500999E-01	-9.086752E-15 -5.535660E-01	3.0E+01 4.8E+01
18	-1.303304E+00 -2.578598E+00	2.001457E+00 3.959899E+00	0.0 0.0	0.0 0.0	0.0	2.001457E+00 3.959899E+00	-1.303304E+00 -2.578598E+00	5.6E+00 9.5E+00
19	-2.586905E+00 5.589511E+00	3.972657E+00 -8.583696E+00	0.0 0.0	0.0 0.0	0.0	3.972657E+00 5.589511E+00	-2.586905E+00 -8.583696E+00	3.7E+00 2.1E+00
20	5.592401E+00 -5.106040E+00	-8.588134E+00 7.841241E+00	0.0 0.0	0.0 0.0	0.0	5.592401E+00 7.841241E+00	-8.588134E+00 -5.106040E+00	2.3E+00 2.1E+00
21	-5.106040E+00 -6.333458E+00	7.841241E+00 9.726162E+00	0.0 0.0	0.0 0.0	0.0	7.841241E+00 9.726162E+00	-5.106040E+00 -6.333458E+00	1.7E+00 3.3E+00
22	-9.593409E+00 2.093796E-13	1.473240E+01 -3.215399E-13	0.0 0.0	0.0 0.0	0.0	1.473240E+01 2.093796E-13	-9.593409E+00 -3.215399E-13	7.6E-01 1.8E+00
23	-9.128204E-15 -7.847512E-01	1.401800E-14 1.205126E+00	0.0 0.0	0.0 0.0	0.0	1.401800E-14 1.205126E+00	-9.128204E-15 -7.847512E-01	2.1E+01 3.3E+01
24	-1.535647E+00 -2.297370E+00	2.358261E+00 3.528024E+00	0.0 0.0	0.0 0.0	0.0	2.358261E+00 3.528024E+00	-1.535647E+00 -2.297370E+00	6.4E+00 1.1E+01
25	-2.305677E+00 6.384310E+00	3.540781E+00 -9.804252E+00	0.0 0.0	0.0 0.0	0.0	3.540781E+00 6.384310E+00	-2.305677E+00 -9.804252E+00	3.1E+00 1.8E+00
26	6.387782E+00 -5.320236E+00	-9.809585E+00 8.170177E+00	0.0 0.0	0.0 0.0	0.0	6.387782E+00 8.170177E+00	-9.809585E+00 -5.320236E+00	2.2E+00 1.8E+00
27	-5.320236E+00 -7.557231E+00	8.170177E+00 1.160548E+01	0.0 0.0	0.0 0.0	0.0	8.170177E+00 1.160548E+01	-5.320236E+00 -7.557231E+00	1.2E+00 2.5E+00
28	-1.081780E+01 1.395864E-13	1.661267E+01 -2.143599E-13	0.0 0.0	0.0 0.0	0.0	1.661267E+01 1.395864E-13	-1.081780E+01 -2.143599E-13	5.7E-01 1.5E+00
29	-7.637480E-15 -1.078272E+00	1.172872E-14 1.655881E+00	0.0 0.0	0.0 0.0	0.0	1.172872E-14 1.655881E+00	-7.637480E-15 -1.078272E+00	1.5E+01 2.4E+01
30	-1.829883E+00 -1.727966E+00	2.810114E+00 2.653602E+00	0.0 0.0	0.0 0.0	0.0	2.810114E+00 2.653602E+00	-1.829883E+00 -1.727966E+00	8.3E+00 1.4E+01
31	-1.736274E+00 7.817353E+00	2.666360E+00 -1.200495E+01	0.0 0.0	0.0 0.0	0.0	2.666360E+00 7.817353E+00	-1.736274E+00 -1.200495E+01	2.3E+00 1.2E+00
32	7.820280E+00 -5.170626E+00	-1.200944E+01 7.940426E+00	0.0 0.0	0.0 0.0	0.0	7.820280E+00 7.940426E+00	-1.200944E+01 -5.170626E+00	2.3E+00 1.2E+00

TABLE A-9. HEGS-PALLETIZED FLOOR ANALYSIS (continued)

S T R E S S E S I N B A R E L E M E N T S (C B A R)

ELEMENT ID.	SA1 SB1	SA2 SB2	SA3 SB3	SA4 SB4	AXIAL STRESS	SA-MAX SB-MAX	SA-MIN SB-MIN	M.S.-T M.S.-C
33	-5.170628E+00	7.940426E+00	0.0	0.0	0.0	7.940426E+00	-5.170628E+00	9.5E-01
	-8.690513E+00	1.334584E+01	0.0	0.0		1.334584E+01	-8.690513E+00	2.1E+00
34	-1.195132E+01	1.835339E+01	0.0	0.0	0.0	1.835339E+01	-1.195132E+01	4.2E-01
	1.395864E-13	-2.143599E-13	0.0	0.0		1.395864E-13	-2.143599E-13	1.3E+00
35	-1.098793E-02	1.057235E-02	0.0	0.0	0.0	1.057235E-02	-1.098793E-02	3.1E+01
	-8.370725E-01	8.054132E-01	0.0	0.0		8.054132E-01	-8.370725E-01	3.1E+01
36	-8.370725E-01	8.054132E-01	0.0	0.0	0.0	8.054132E-01	-8.370725E-01	2.3E+01
	-1.142037E+00	1.098843E+00	0.0	0.0		1.098843E+00	-1.142037E+00	2.3E+01
37	-1.149583E+00	1.106104E+00	0.0	0.0	0.0	1.106104E+00	-1.149583E+00	2.0E+01
	-1.301800E+00	1.252564E+00	0.0	0.0		1.252564E+00	-1.301800E+00	2.0E+01
38	-1.304960E+00	1.255605E+00	0.0	0.0	0.0	1.255605E+00	-1.304960E+00	1.9E+01
	-1.341570E+00	1.290830E+00	0.0	0.0		1.290830E+00	-1.341570E+00	1.9E+01
39	-1.339547E+00	1.288883E+00	0.0	0.0	0.0	1.288883E+00	-1.339547E+00	1.9E+01
	-1.212270E+00	1.166420E+00	0.0	0.0		1.166420E+00	-1.212270E+00	1.9E+01
40	2.745903E-03	-2.773438E-03	0.0	0.0	0.0	2.745903E-03	-2.773438E-03	1.4E+00
	-1.083496E+01	1.094361E+01	0.0	0.0		1.094361E+01	-1.083496E+01	1.5E+00
41	-1.063303E+01	1.094166E+01	0.0	0.0	0.0	1.094166E+01	-1.063303E+01	3.9E-01
	-1.857732E+01	1.876361E+01	0.0	0.0		1.876361E+01	-1.857732E+01	4.5E-01
42	-1.857665E+01	1.876293E+01	0.0	0.0	0.0	1.876293E+01	-1.857665E+01	1.0E-01
	-2.339798E+01	2.363261E+01	0.0	0.0		2.363261E+01	-2.339798E+01	1.5E-01
43	-2.339842E+01	2.363305E+01	0.0	0.0	0.0	2.363305E+01	-2.339842E+01	5.2E-02
	-2.447439E+01	2.471981E+01	0.0	0.0		2.471981E+01	-2.447439E+01	1.0E-01
44	-2.447593E+01	2.472136E+01	0.0	0.0	0.0	2.472136E+01	-2.447593E+01	5.2E-02
	-2.160527E+01	2.182192E+01	0.0	0.0		2.182192E+01	-2.160527E+01	1.0E-01
45	-2.074648E-03	1.996182E-03	0.0	0.0	0.0	1.996182E-03	-2.074648E-03	1.6E+00
	-1.040241E+01	1.000898E+01	0.0	0.0		1.000898E+01	-1.040241E+01	1.6E+00
46	-1.040550E+01	1.001194E+01	0.0	0.0	0.0	1.001194E+01	-1.040550E+01	5.5E-01
	-1.743811E+01	1.677858E+01	0.0	0.0		1.677858E+01	-1.743811E+01	5.5E-01
47	-1.744214E+01	1.678245E+01	0.0	0.0	0.0	1.678245E+01	-1.744214E+01	2.4E-01
	-2.175327E+01	2.093053E+01	0.0	0.0		2.093053E+01	-2.175327E+01	2.4E-01
48	-2.175702E+01	2.093414E+01	0.0	0.0	0.0	2.093414E+01	-2.175702E+01	1.9E-01
	-2.266949E+01	2.181210E+01	0.0	0.0		2.181210E+01	-2.266949E+01	1.9E-01

TABLE A-9. HEGS-PALLETIZED FLOOR ANALYSIS (continued)

	STRESSES IN BAR ELEMENTS (CBAR)							
ELEMENT ID.	SA1 SB1	SA2 SB2	SA3 SB3	SA4 SB4	AXIAL STRESS	SA-MAX SB-MAX	SA-MIN SB-MIN	M.S.-T M.S.-C
49	-2.267247E+01 -1.993063E+01	2.181496E+01 1.917682E+01	0.0 0.0	0.0 0.0	0.0	2.181496E+01 1.917682E+01	-2.267247E+01 -1.993063E+01	1.9E-01 1.9E-01
50	-4.280290E-04 -3.685857E+00	4.684646E-04 4.034056E+00	0.0 0.0	0.0 0.0	0.0	4.684646E-04 4.034056E+00	-4.280290E-04 -3.685857E+00	5.4E+00 6.3E+00
51	-3.698732E+00 -8.433984E+00	4.048148E+00 9.230735E+00	0.0 0.0	0.0 0.0	0.0	4.048148E+00 9.230735E+00	-3.698732E+00 -8.433984E+00	1.8E+00 2.2E+00
52	-8.432378E+00 -1.148844E+01	9.228977E+00 1.257375E+01	0.0 0.0	0.0 0.0	0.0	9.228977E+00 1.257375E+01	-8.432378E+00 -1.148844E+01	1.1E+00 1.4E+00
53	-1.148737E+01 -1.182341E+01	1.257257E+01 1.294036E+01	0.0 0.0	0.0 0.0	0.0	1.257257E+01 1.294036E+01	-1.148737E+01 -1.182341E+01	1.0E+00 1.3E+00
54	-1.182338E+01 -9.791922E+00	1.294033E+01 1.071696E+01	0.0 0.0	0.0 0.0	0.0	1.294033E+01 1.071696E+01	-1.182338E+01 -9.791922E+00	1.0E+00 1.3E+00
55	6.307897E-03 -6.448959E+00	-6.903799E-03 7.058187E+00	0.0 0.0	0.0 0.0	0.0	6.307897E-03 7.058187E+00	-6.903799E-03 -6.448959E+00	2.7E+00 3.2E+00
56	-6.440135E+00 -1.585428E+01	7.048529E+00 1.735202E+01	0.0 0.0	0.0 0.0	0.0	7.048529E+00 1.735202E+01	-6.440135E+00 -1.585428E+01	5.0E-01 7.3E-01
57	-1.584322E+01 -2.199419E+01	1.733992E+01 2.407196E+01	0.0 0.0	0.0 0.0	0.0	1.733992E+01 2.407196E+01	-1.584322E+01 -2.199419E+01	8.0E-02 2.3E-01
58	-2.198414E+01 -2.273974E+01	2.406096E+01 2.488795E+01	0.0 0.0	0.0 0.0	0.0	2.406096E+01 2.488795E+01	-2.198414E+01 -2.273974E+01	4.5E-02 1.9E-01
59	-2.273197E+01 -1.900085E+01	2.487944E+01 2.079584E+01	0.0 0.0	0.0 0.0	0.0	2.487944E+01 2.079584E+01	-2.273197E+01 -1.900085E+01	4.5E-02 1.9E-01
60	-4.766539E-15 -1.551381E+00	7.319875E-15 2.382424E+00	0.0 0.0	0.0 0.0	0.0	7.319875E-15 2.382424E+00	-4.766539E-15 -1.551381E+00	9.9E+00 1.6E+01
61	-2.321119E+00 -9.510548E-01	3.564494E+00 1.460515E+00	0.0 0.0	0.0 0.0	0.0	3.564494E+00 1.460515E+00	-2.321119E+00 -9.510548E-01	6.3E+00 1.1E+01
62	-9.595930E-01 1.012480E+01	1.473627E+00 -1.554845E+01	0.0 0.0	0.0 0.0	0.0	1.473627E+00 1.012480E+01	-9.595930E-01 -1.554845E+01	1.5E+00 7.4E-01
63	1.012524E+01 -4.750172E+00	-1.554913E+01 7.294741E+00	0.0 0.0	0.0 0.0	0.0	1.012524E+01 7.294741E+00	-1.554913E+01 -4.750172E+00	1.5E+00 7.4E-01
64	-4.750172E+00 -9.891406E+00	7.294741E+00 1.519003E+01	0.0 0.0	0.0 0.0	0.0	7.294741E+00 1.519003E+01	-4.750172E+00 -9.891406E+00	7.1E-01 1.7E+00

TABLE A-9. HEGS-PALLETIZED FLOOR ANALYSIS (continued)

S T R E S S E S   I N   B A R   E L E M E N T S   (C H A R)

ELEMENT ID.	SA1 SB1	SA2 SB2	SA3 SB3	SA4 SB4	AXIAL STRESS	SA-MAX SB-MAX	SA-MIN SB-MIN	M.S.-T M.S.-C
65	-1.324192E+01 6.979319E-14	2.033535E+01 -1.071800E-13	0.0 0.0	0.0 0.0	0.0	2.033535E+01 6.979319E-14	-1.324192E+01 -1.071800E-13	2.4E-01 1.0E+00
66	0.0 -4.958302E+00	0.0 5.080227E+00	0.0 0.0	0.0 0.0	0.0	0.0 5.080227E+00	0.0 -4.958302E+00	4.1E+00 4.4E+00
67	-5.197983E+00 3.632417E+00	5.325802E+00 -3.721738E+00	0.0 0.0	0.0 0.0	0.0	5.325802E+00 3.632417E+00	-5.197983E+00 -3.721738E+00	3.9E+00 4.2E+00
68	3.630515E+00 1.513685E+01	-3.719790E+00 -1.550910E+01	0.0 0.0	0.0 0.0	0.0	3.630515E+00 1.513688E+01	-3.719790E+00 -1.550910E+01	7.2E-01 7.4E-01
69	1.513236E+01 -2.764290E+00	-1.550447E+01 2.832264E+00	0.0 0.0	0.0 0.0	0.0	1.513236E+01 2.832264E+00	-1.550447E+01 -2.764290E+00	7.2E-01 7.4E-01
70	-2.764290E+00 -1.798041E+01	2.832264E+00 1.842256E+01	0.0 0.0	0.0 0.0	0.0	2.832264E+00 1.842256E+01	-2.764290E+00 -1.798041E+01	4.1E-01 5.0E-01
71	-1.891321E+01 -8.237734E-14	1.937829E+01 8.440301E-14	0.0 0.0	0.0 0.0	0.0	1.937829E+01 8.440301E-14	-1.891321E+01 -8.237734E-14	3.4E-01 4.3E-01
72	-1.205463E+00 -8.530001E-01	1.159871E+00 8.207384E-01	0.0 0.0	0.0 0.0	0.0	1.159871E+00 8.207384E-01	-1.205463E+00 -8.530001E-01	2.1E+01 2.1E+01
73	-8.427531E-01 -1.182411E-02	8.108789E-01 1.137690E-02	0.0 0.0	0.0 0.0	0.0	8.108789E-01 1.137690E-02	-8.427531E-01 -1.182411E-02	3.1E+01 3.1E+01
74	-9.792353E+00 -5.959527E+00	1.071743E+01 6.522518E+00	0.0 0.0	0.0 0.0	0.0	1.071743E+01 6.522518E+00	-9.792353E+00 -5.959527E+00	1.4E+00 1.8E+00
75	-5.959565E+00 -5.571827E-04	6.522494E+00 6.098192E-04	0.0 0.0	0.0 0.0	0.0	6.522494E+00 6.098192E-04	-5.959565E+00 -5.571827E-04	3.0E+00 3.5E+00
76	-2.160804E+01 -1.450714E+01	2.182472E+01 1.465262E+01	0.0 0.0	0.0 0.0	0.0	2.182472E+01 1.465262E+01	-2.160804E+01 -1.450714E+01	1.9E-01 2.5E-01
77	-1.451111E+01 4.654452E-03	1.465663E+01 -4.701125E-03	0.0 0.0	0.0 0.0	0.0	1.465663E+01 4.654452E-03	-1.451111E+01 -4.701125E-03	7.7E-01 8.6E-01
78	-1.899443E+01 -1.181290E+01	2.078882E+01 1.292885E+01	0.0 0.0	0.0 0.0	0.0	2.078882E+01 1.292885E+01	-1.899443E+01 -1.181290E+01	2.5E-01 4.2E-01
79	-1.180633E+01 -7.078564E-03	1.292167E+01 7.747270E-03	0.0 0.0	0.0 0.0	0.0	1.292167E+01 7.747270E-03	-1.180633E+01 -7.078564E-03	1.0E+00 1.3E+00
80	-1.993315E+01 -1.330032E+01	1.917925E+01 1.279728E+01	0.0 0.0	0.0 0.0	0.0	1.917925E+01 1.279728E+01	-1.993315E+01 -1.330032E+01	3.6E-01 3.5E-01
81	-1.330292E+01 2.802968E-03	1.279979E+01 -2.696956E-03	0.0 0.0	0.0 0.0	0.0	1.279979E+01 2.802968E-03	-1.330292E+01 -2.696956E-03	1.0E+00 1.0E+00

FLOOR PLATING

The HEGS-Palletized plating is essentially identical to that of the HEGS-10. See page 96 for description of expected performance.

SUPERSTRUCTURE ANALYSIS

The loads acting on the superstructure of the HEGS-Palletized module are similar to those acting on the superstructure of the HEGS-20 module. Consequently, the sizes, stresses and margins of safety for the HEGS-Palletized superstructure members are, in general, similar to those previously obtained for the HEGS-20 superstructure members. Exceptions to this generalization are the corner columns, the intermediate side members, the shear webs, and the end diagonals. Member sizes, materials, loads, and margins of safety for these four members are presented.

CORNER COLUMNS

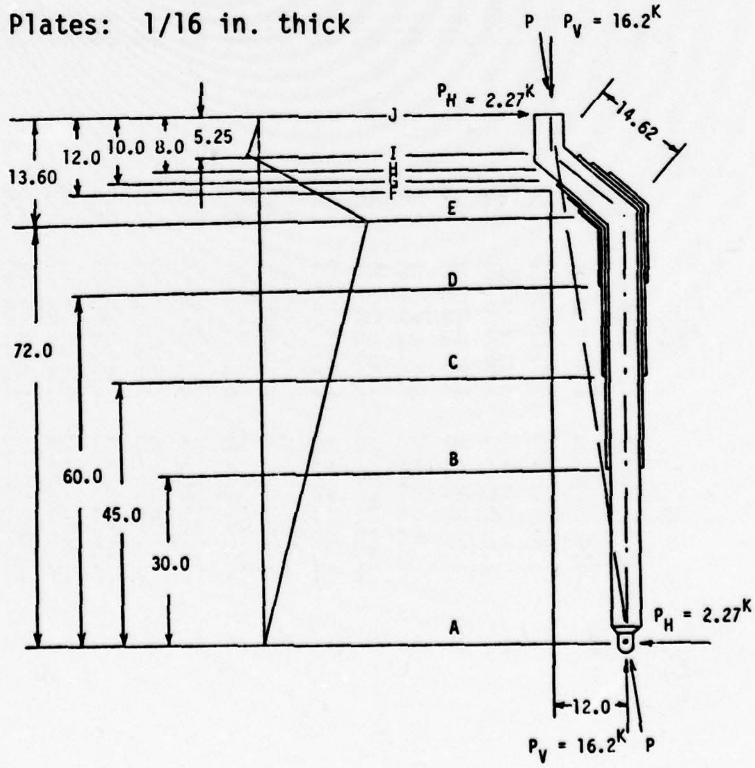
Tubing

Material: 6066-T6 aluminum

Limit Load: 9.3 kips, - 16.2 kips

Sizes:

- Tubing: 4 x 4 x .125 in. square tubing
- Cover Plates: 1/16 in. thick



The ultimate combined stress due to axial load and bending moment due to eccentricity is obtained using the following expression:

$$f_{bu} = 1.5 \left[\frac{P_v}{A} + \frac{Mc}{I}\right]$$

The margin of safety is:

$$MS_{bu} = \frac{F_{bu}}{f_{bu}} - 1$$

Ultimate stresses and their respective margins of safety for the critical sections of the corner columns are as follows:

SECTION	P_v KIPS	M KIP-IN.	A $IN.^2$	I $IN.^4$	C IN.	f_{bu} KSI	F_{bu}* KSI	MS_{bu}
A	16.2	0	1.938	4.854	2.0	12.54	58.0	3.62
B	16.2	68.1	1.938	4.854	2.0	54.63	58.0	.06
C	16.2	102.2	2.442	6.935	2.032	54.85	58.0	.06
D	16.2	136.2	2.938	9.108	2.063	54.54	58.0	.06
E	16.2	163.4	3.438	11.430	2.094	45.52	58.0	.27
F	16.2	129.9	2.938	9.108	2.063	52.40	58.0	.11
G	16.2	88.0	2.442	6.934	2.032	48.63	58.0	.19
H	16.2	45.8	1.938	4.854	2.0	40.84	58.0	.42
I	16.2	- 11.9	1.938	4.854	2.0	19.89	34.0	.71
J	16.2	0	1.938	4.854	2.0	12.54	34.0	1.71

*F_{bu} = 58.0 ksi after heat treatment

F_{bu} = 34.0 ksi after welding without subsequent heat treatment

Intermediate Side Member

Material: 6061-T6 aluminum tubing

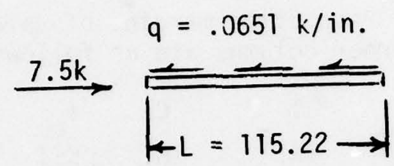
Limit Load: 7.5 kips

Ultimate Load = 1.5 Limit Load = 1.5 (7.5) = 11.25 kips

Size: 3-3/4 in. OD x .049 in. thick

$$A = \pi D_m t = \pi(3.701)(.049) = .570 \text{ in.}^2$$

$$I = \frac{\pi}{64}[D_o^4 - D_i^4] = \frac{\pi}{64}[(3.75)^4 - (3.652)^4] = .976 \text{ in.}^4$$



Buckling

From page B3.44.33-1, Reference 12

$$P = 0 \qquad qL = .0651\ (115.22) = 7.5 \text{ kips}$$

For $\dfrac{\text{Shear Load}}{\text{Largest Comp. Load}} = \dfrac{qL}{(qL + P)} = \dfrac{7.5}{7.5 + 0} = 1.0$

The buckling coefficient, m = .53

$$(qL + P)_{CR} = \frac{\pi^2 EI}{mL^2} = \frac{\pi^2\ (10{,}100)(.976)}{.53\ (115.22)^2} = 13.83 \text{ kips}$$

Ultimate Load = 11.25

$$MS_{cu} = \frac{13.83}{11.25} - 1 = \underline{\underline{.23}}$$

Compression Yield Stress at Tube End (Heat-affected Zone)

Limit Compression Load, P_y = - 7.5 kips

$$f_{cy} = \frac{P_y}{A} = \frac{7.5}{.570} = 13.16 \text{ ksi}$$

F_{cy} = 20.0 ksi

$$MS_{cy} = \frac{20.0}{13.16} - 1 = \underline{\underline{.52}}$$

13. STRUCTURES MANUAL, Grumman Aircraft Engineering Corporation, Bethpage, New York, March 1966.

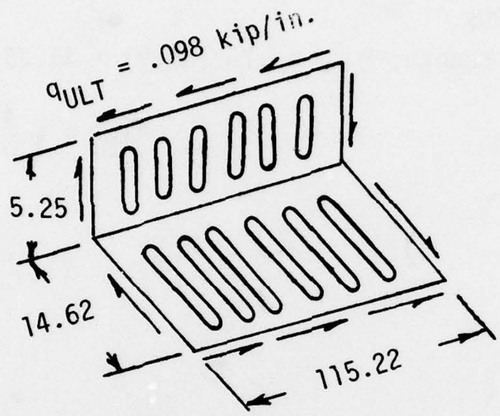
SHEAR WEBS

Material: 6061-T6 beaded aluminum sheet

Limit Shear Flow, q_{LIMIT} = 7.5/115.25 = .065 kip/in.

Ultimate Shear Flow, q_{ULT} = 1.5 (.065) = .098 kip/in.

Thickness, t = 0.65



Shear Buckling of Beaded Panels

Page C10.16, Figure C10-18, Reference 13

For Bead Depth = .25 inches

Panel Height = 14.62 inches

Maximum allowable Shear Flow, Q = .260 kip/in.

$$MS_s = \frac{.260}{.098} - 1 = \underline{\underline{1.65}}$$

Ultimate Shear Stress

Ultimate Shear Stress, $f_s = \frac{q_{ULT}}{t} = \frac{.098}{.032} = 3.06$ ksi

F_{su} = 15.0 ksi (as welded)

$$MS_{su} = \frac{15.0}{3.06} - 1 = \underline{\underline{3.90}}$$

14. Bruhn, E. F., ANALYSIS AND DESIGN OF FLIGHT VEHICLE STRUCTURES, Tri-State Offset Company, 1973.

END DIAGONALS

Material: Kevlar

Limit Load: P_y = 18.2 kips

Size: PS29 - 6 x 37 x .085

Minimum Cable Breaking Strength = 55.0 kips

End Fitting Efficiency = 75%

Ultimate Diagonal Strength, P_{ULT} = .75 (55.0) = 41.25 kips

$$MS_{tu} = \frac{41.25}{1.5\ (18.2)} - 1 = \underline{\underline{.51}}$$

APPENDIX B

CRITICAL ITEM DEVELOPMENT SPECIFICATION
FOR THE EXPLORATORY DEVELOPMENT OF A
HELICOPTER EXTERNAL GONDOLA SYSTEM (HEGS)

1.0 SCOPE

This specification establishes the performance, design, development, and test requirements for the helicopter external gondola system (HEGS) critical item.

2.0 APPLICABLE DOCUMENTS

2.1 Government documents. The following documents of the issue in effect on the date of the request for proposal form a part of this specification to the extent specified herein.

SPECIFICATIONS

Federal

None

Military

MIL-A-8421	Air Transportability Requirements, General Specifications for
MIL-D-1000	Drawing, Engineering and Associated Lists

Other Government Activity

None

STANDARDS

Federal

None

Military

MIL-STD-100	Engineering Drawing Practices
MIL-STD-147	Palletized Unit Loads on 40" x 48" Pallets

MIL-STD-209	Slinging and Tiedown Provisions for Lifting and Tying Down Military Equipment
MIL-STD-889	Dissimilar Metals

Other Government Activity

None

OTHER PUBLICATIONS

Manuals

None

Regulations

AR 70-47	Engineering for Transportability

Handbooks

MIL-HDBK-5B	Military Standardization Handbook, Metallic Materials and Elements for Aerospace Vehicle Structures

2.2 Non-Government documents. The following documents of the issue in effect on the date of the request for proposal form a part of this specification to the extent specified herein.

SPECIFICATIONS

None

STANDARDS

ANSI MH5.1-1971	Basic Requirements for Cargo Containers

3.0 REQUIREMENTS

3.1 Definition. The helicopter external gondola system (HEGS) specified herein shall consist of a family of three gondola module configurations designed to be suspended below the CH-47D and/or UH-60 (Black Hawk) helicopters (as applicable) for the purpose of rapidly deploying equipment and supplies. The three configurations are designated the HEGS-10, HEGS-20, and HEGS-Palletized gondola modules.

3.1.1 HEGS-10 gondola module. This module is a general purpose 8-foot x 10-foot cargo gondola used for transporting breakbulk/general cargo, equipment, spare parts, rations, and ammunitions.

3.1.2 HEGS-20 gondola module. This module is a general purpose 8-foot x 20-foot cargo gondola used for transporting breakbulk/general purpose cargo, equipment, spare parts, rations, ammunitions, artillery, and vehicles.

3.1.3 HEGS-Palletized gondola module. This module is a palletized cargo gondola configured to accept 463L pallets (463L Air Cargo Handling System, MIL-A-8421), or 40-inch x 48-inch pallets, and other special palletized cargo.

3.2 Characteristics.

3.2.1 Performance.

3.2.1.1 Aerodynamic stability. The HEGS modules shall have a porous floor in order to enhance aerodynamic stability in the unloaded mode. Sides, ends, and top shall be of generally open and low drag configuration.

3.2.1.2 Loading/unloading operations. The HEGS modules shall be capable of being rapidly loaded/unloaded from sides and ends, either manually or with forklift equipment. End and side structures shall be capable of rapid connect/disconnect to provide accessibility for roll-on/roll-off/drive-through capability.

3.2.1.3 Cargo containment. The HEGS modules shall provide for the containment of cargo within the flight envelope of the CH-47D and UH-60 helicopters, as appropriate.

3.2.1.4 Structural strength. The structure of the HEGS modules shall be capable of withstanding the limit loads for the suspension, racking, and stacking conditions without permanent deformation that will interfere with proper function, and shall be capable of withstanding the ultimate loads for these conditions without failing, where the ultimate load is defined as 1.5 times the limit load.

3.2.1.4.1 Suspension conditions. The HEGS modules shall be capable of being suspended below the CH-47D or UH-60 helicopters, as applicable, using either a single-point suspension system or a two-point suspension system with sling angles not to exceed 30 degrees from the vertical. The distance between the two CH-47D cargo hooks for the two-point suspension condition is 13 feet. The HEGS modules shall be designed in accordance with AR 70-47, Appendix D, which defines the limit lift point factors to be applied to the module suspension points. The floor shall be capable of sustaining limit floor loads of 300 pounds per square foot, and the load asymmetry factor shall be based on a 60/40 floor load distribution (longitudinal and lateral CG location). The vertical CG location can vary from 12 inches to 24 inches above the surface of the floor.

3.2.1.4.2 Racking conditions (longitudinal and lateral). The HEGS modules shall be capable of resisting a .6-g limit load applied to an upper corner

fitting in either the longitudinal or lateral direction with these loads being reacted at the diagonally opposite lower corner fitting located in the same plane as the applied load.

3.2.1.4.3 Stacking condition. The HEGS modules shall be capable of being stacked two units high with the upper unit applying a 1.8-g downward limit load to the upper corner fittings of the lower module, while a 1.0-g downward limit load acts on the floor of the lower module. The loads shall be applied in accordance with the 60/40 load distribution (design criteria).

3.2.1.4.4 Impact forces. The HEGS modules shall be capable of sustaining impact forces associated with normal helicopter external cargo handling operations. Specifically, the impact loads associated with edge or corner strikes which may occur due to uneven terrain or uneven attitude of the gondola shall be considered.

3.2.1.5 Corrosion resistance. Materials used in the fabrication of the HEGS modules shall be corrosion resistant, and preferably will not require paint or other protective coatings.

3.2.1.6 Wear and abrasion resistance. Materials used in the fabrication of the HEGS modules shall be resistant to the normal wear and abrasion associated with cargo handling and loading/unloading operations.

3.2.1.7 Roller system. The floor structure (or base) of the HEGS-Palletized module shall incorporate provisions for a roller-type or equivalent system compatible with the loading/unloading of 463L pallets and 40-inch x 48-inch cargo pallets. Provisions for securing 463L and other cargo pallets against longitudinal and lateral movement while in transit shall also be incorporated in the floor structure of the HEGS-Palletized module.

3.2.1.8 Module handling. The HEGS modules shall be compatible with helicopter container lift adapter and ground transport equipment.

3.2.1.9 Loading ramps. Provisions for attaching loading/unloading ramps shall be incorporated around the periphery of the floor structure. Provisions shall also be incorporated for stowing these ramps during flight.

3.2.1.10 Wheel chocks. Provisions for attaching and stowing wheel chocks shall be incorporated.

3.2.2 Physical characteristics.

3.2.2.1 Weight.

3.2.2.1.1 Design operating gross weight. The design operating gross weights for the three gondola module configurations are:

HEGS-10	8000 pounds

HEGS-20 25000 pounds

HEGS-Palletized 25000 pounds

3.2.2.1.2 Design empty weight. The design empty weight shall be as light as practical. Weight goals for the three gondola module configurations are:

HEGS-10 600 pounds

HEGS-20 1300 pounds

HEGS-Palletized 1600 pounds (exclusive of floor roller system)

3.2.2.2 Configuration and dimensions.

3.2.2.2.1 HEGS-10 modules.

3.2.2.2.1.1 Planform. The top and bottom planform shall conform to dimensional specifications for 8-foot-wide x 10-foot-long units defined by ANSI Document MH 5.1-1971.

3.2.2.2.1.2 Interior width. The effective lateral interior width shall be the maximum obtainable, consistent with design and materials, but not less than 88 inches.

3.2.2.2.1.3 Overall height. The overall height shall be 8-feet-6-inches in accordance with dimensions defined by ANSI Document MH 5.1-1971, and shall also be consistent with the height selected for the HEGS-20 and HEGS-Palletized modules.

3.2.2.2.1.4 Corner fitting dimensions. Dimensions for the International Organization for Standardization (ISO) upper and lower corner fittings shall be in accordance with those specified by ANSI Document MH 5.1-1971. Thicknesses of these fittings may vary from those specified, provided they are consistent with the structural capabilities of the material selected and allow proper function of standard handling equipment.

3.2.2.2.2 HEGS-20 modules.

3.2.2.2.2.1 Planform. The top and bottom planform shall conform to dimensional specifications for 8-foot-wide x 20-foot-long units defined by ANSI Document MH 5.1-1971.

3.2.2.2.2.2 Interior width. The effective lateral interior width at the ends of the module shall be the maximum available consistent with design and materials, but not less than 88 inches. The effective lateral interior width at locations removed from the vertical end members shall be a minimum of 89-1/2 inches between center posts, and shall be consistent with the side loading of 88-inch-wide x 108-inch-long 463L pallets defined by MIL-A-8421.

3.2.2.2.2.3 Overall height. The overall height shall be 8-feet-6-inches in accordance with dimensions defined by ANSI Document MH 5.1-1971 and shall also be consistent with the height selected for the HEGS-10 and HEGS-Palletized modules.

3.2.2.2.2.4 Corner fitting dimensions. Dimensions for the ISO upper and lower corner fittings shall be in accordance with those specified by ANSI Document MH5.1-1971. Thicknesses of these fittings may vary from those specified, provided they are consistent with the structural capabilities of the materials selected and allow proper function of standard handling equipment.

3.2.2.2.3 HEGS-Palletized modules.

3.2.2.2.3.1 Top planform. The top planform configuration shall conform to the dimensional specifications for 8-foot-wide x 20-foot-long units, ANSI Document MH 5.1-1971.

3.2.2.2.3.2 Bottom planform. The exterior width of the base shall be the minimum attainable consistent with an interior width of 110 inches + 2 inches - 0. The exterior length of the base shall conform with dimensional specifications for 20-foot-long units, ANSI Document MH 5.1-1971.

3.2.2.2.3.3 Underside of base. The underside of the base shall provide for attachment points that conform with dimensional specifications for 8-foot-wide x 20-foot-long units, ANSI Document MH 5.1-1971.

3.2.2.2.3.4 Overall height. The overall height shall be 8-feet-6-inches in accordance with dimensions defined by ANSI Document MH 5.1-1971, and shall also be consistent with the height selected for the HEGS-10 and HEGS-20 modules.

3.2.2.2.3.5 Clear interior cargo height. The clear 110 inch + 2 inch - 0 interior width shall extend vertically for 6 feet above the floor surface or for a distance specified by the contracting agency.

3.2.2.2.3.6 Corner fitting dimensions. Dimensions for the ISO upper corner fittings and lower attachment fittings (both conforming to the dimensions for an 8-foot-wide x 20-foot-long unit) shall be in accordance with ANSI Document MH 5.1-1971. Thicknesses of these fittings may vary from those specified, provided they are consistent with the structural capabilities of the material selected and allow proper function of standard handling equipment.

3.2.3 Reliability. The design configurations of the HEGS modules shall be as simple as possible consistent with mission performance requirements, and they shall be constructed for an unlimited service life. Maintenance, other than periodic adjustments, shall not be necessary between overhauls. All components shall be designed for "on-condition" overhaul.

3.2.4 Maintainability. The HEGS modules shall be designed and fabricated as specified herein to provide the following:

a. Minimum number of parts consistent with reliability and performance specified herein

b. Minimum amount of training and time necessary for assembly, maintenance, and disassembly

c. Permit adjustment, servicing, replacement of parts and components, and other maintenance with minimum disturbance to other parts or components

d. Permit maintenance with general-purpose tools and equipment normally available

e. Minimum number of tools required for maintenance and component replacement.

3.2.4.1 Repair time allowance. The HEGS module mean-time-to-repair (MTTR) shall not exceed one hour. Maintenance man-hours per operating hour shall not exceed .004.

3.2.5 Environmental conditions. The HEGS modules shall be functional at ambient temperatures of - 65°F to + 125°F and shall suffer no detrimental effects when exposed to rain, ice, wind-blown sand, salt spray, or sunlight.

3.2.6 Transportability. The HEGS modules shall provide stable aerodynamic flight characteristics in both loaded and unloaded modes within the flight envelope of the CH-47D and UH-60 helicopters as applicable. They shall also be compatible with helicopter container lift adapter and ground transport equipment.

3.3 Design and construction. The HEGS modules shall be designed and fabricated using commercial standards and procedures to produce low-cost, lightweight, impact-resistant units.

3.3.1 Materials, processes, and parts.

3.3.1.1 Metallic materials. All metallic materials used in the construction of the HEGS modules shall be corrosion-resistant or treated to resist corrosion due to fuels, salt spray, or atmospheric conditions likely to be met in storage or normal service. Unless protected against electrolytic corrosion, dissimilar metals shall not be used in intimate contact with each other. Dissimilar metals are defined in MIL-STD-889. Material properties presented in MIL-HDBK-5B, or approved commercial specifications, shall be used to establish the structural adequacy of the HEGS modules; where insufficient data is available for this purpose, tests shall be performed to obtain the required material properties.

3.3.1.2 Nonmetallic materials. Nonmetallic and composite materials used in the construction of the HEGS modules shall be resistant to or protected

from deterioration when exposed to climatic and environmental conditions likely to occur during service usage. The protection against such deterioration shall be provided in a manner that will in no way prevent compliance with the performance requirements of this specification. Any protective coating used shall provide maximum protection against cracking, chipping, peeling, or scaling with age or extreme climatic and environmental conditions.

3.3.2 Workmanship. Parts and components shall be fabricated and finished in a thoroughly workmanlike manner. Particular attention shall be given to freedom from burrs, sharp edges, accuracy of critical dimensions, thoroughness of welding, alignment of parts, and tightness of bolts. Dimensions and tolerances not specified shall be as close as is consistent with good shop practices. Dimensions and tolerances that may affect interchangeability shall be held or limited accordingly.

3.3.3 Interchangeability. Components and parts for a given HEGS module configuration shall be designed for interchangeability within that configuration. In particular, column assemblies, and diagonal parts and assemblies shall be designed to be quickly replaced in the event of damage.

3.3.4 Safety. The HEGS modules shall be designed as follows to protect personnel working on or near the modules:

a. Features shall be incorporated to prevent the collapse of the corner columns and upper structure when both sets of end diagonals are removed or when all side diagonals (and center columns for the HEGS-20 and HEGS-Palletized modules) are removed during loading/unloading operations.

b. Features shall be provided to permit the assembly or disassembly of diagonals and center columns, where applicable, by personnel wearing arctic clothing.

c. Sharp edges, burrs, and sharp weld splatter shall be removed.

d. Nonskid surfaces shall be provided for working surfaces.

3.4 Documentation. Drawings and associated lists for the HEGS modules shall be in accordance with MIL-D-1000.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 General. On completion of construction, each developmental HEGS module shall be subjected to the tests and inspections specified in the approved test plan to verify the performance and physical characteristics set forth in Section 3 of this specification. These tests and inspections will be conducted by the Contractor and monitored by a designated Government representative. Data shall be recorded in the process of conducting the aforementioned tests and inspections, and shall be used to

verify that the HEGS modules meet the performance requirements and capabilities, and possess the physical characteristics cited in this specification.

4.2 Classification of tests. The HEGS module inspections and tests shall be classified as developmental. The developmental HEGS modules shall be tested for acceptance on the basis of their capability to withstand the loads and to achieve the functional requirements specified in Section 3 of this specification.

The HEGS modules shall be inspected for conformance with the physical, safety, workmanship, and maintainability requirements of Section 3 of this specification.

4.3 Operational field trials. The Government will arrange for and perform the field trials of the developmental HEGS modules to verify aircraft interface compatibility with the specified aircraft, with automated lifting devices, and with ground transport equipment. Field trials will also evaluate the operational procedures, maintainability, flight characteristics, and durability of the developmental HEGS modules.

5.0 PREPARATION FOR DELIVERY

5.1 General. The HEGS modules shall be prepared for shipment, FOB, the procuring Government agency's location, so that no damage shall be incurred in the course of normal commercial transport and handling.

5.2 Specific requirements. The HEGS modules shall be shipped disassembled. All components shall be secured to a shipping pallet and blocked and cushioned to prevent damage from the imposition of routine transport and handling shock loads. All protruding elements shall be fully protected by structurally adequate bracing and covers. All accessory equipment shall be secured to the base of the HEGS modules.

5.3 Marking for shipment. The HEGS modules, when prepared for shipment, shall be conspicuously marked with the complete destination address, the Contractor's address, the contract number under which they were produced, and a concise item description.

5.4 Packing list. A packing list shall be provided with each HEGS module. All parts that are not assembled shall be included on the packing list.

6.0 NOTES

6.1 Intended use. The development HEGS modules will be used to confirm the performance, functioning, and operation of the system to validate the concept of providing a family of gondola modules to effectively, efficiently, and safely transport noncontainerized cargo (vehicles, weapons systems, equipment, breakbulk cargo) externally, below the CH-47D and UH-60 helicopters, as applicable.

6.2 Specification changes. This specification shall be maintained on a current basis through delivery of the developmental HEGS modules. Any and all changes to this specification, deviations or substitutions of materials or components, shall have the prior approval of the procuring Government agency's Contracting Officer and shall be implemented by an approved DD Form 1696, Specification Change Notice.

LIST OF SYMBOLS

A = Area
b = Bending
B = Slenderness ratio factor
c = Fixity coefficient; distance from neutral axis to extreme fiber
CG = Center of gravity
D = Diameter
e = Edge distance
E = Modulus of elasticity
f = Calculated stress
F = Strength
g = Force of gravity
I = Moment of inertia
L = Length
M = Moment
p = Unit pressure
P = Load
q = Shear flow
R = Area ratio, radius
t = Thickness
W = Width or weight
x, y, z = Coordinates
[illegible] = Density

Subscripts and Superscripts

b = Bending
br = Bearing
c = Compression; middiameter
e = Equivalent
H = Horizontal
i = Inner
m = Mean
o = Outer; yield
s = Shear
t = Tension
t = Total
u = Ultimate
V = Vertical
y = Yield
ρ = Radius of gyration

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